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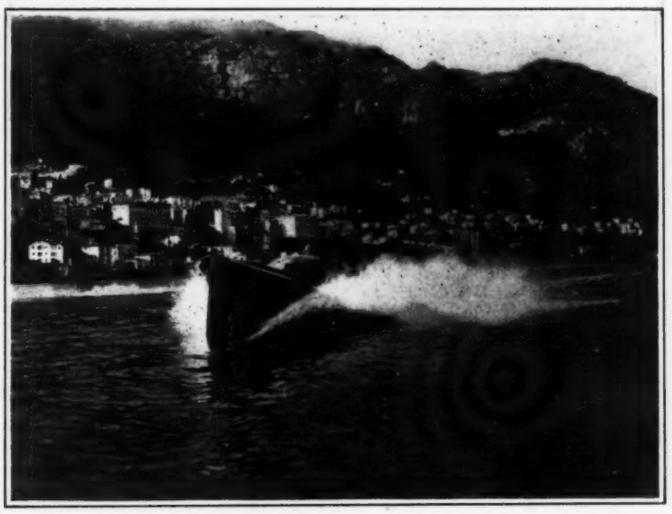
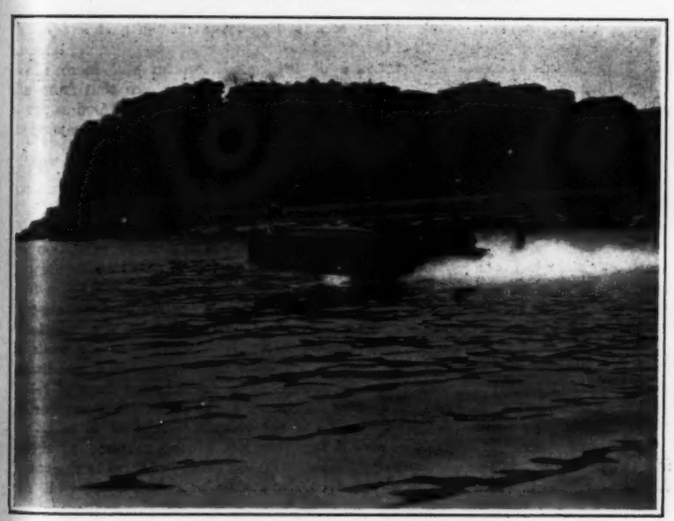
"El Barbaro" competing for the championship.



The "Flambeau," with Despujols motor.



The "Panhard-Tellier" at full speed.

Rounding the stake in the championship race.

The "J'en Veux," with Tellier motor.

The "Despujols" making a sharp turn.

THE MONACO MOTOR BOAT RACES.—[See page 311.]

The Problem of the Meat Supply*

How Will The Demand of the Future Be Met?

THE Standing Committee of the Chamber on Statistics and Standards, which submitted reports on business conditions in the United States as of November 29th, 1913, has made a report on the problem of the meat supply, which is reproduced below:

THE PRESENT SITUATION.

The apparent steady decline of late years in the actual number of all cattle, and of such live stock as we use for food, is a matter of serious national concern. It has become sharply accentuated by the consequent high price of meat, thus adding heavily to the already burdensome cost of living. It took significant form not long ago in a burst of popular feeling, where a temporary "Meat Strike" spread rapidly over the country as a protest against what we believed to be out of joint in existing conditions.

The present apprehension is based largely upon the study of partial, and often superficial statistics, and our usual general tendency to judge the future by the events of the last few years alone.

Nearly all events in Nature have a tendency to operate in cycles, and the error is constantly made of mistaking the arc of the circle for a permanent departure in the shape of a straight line.

There exists to-day a widespread but entirely erroneous belief that the apparent decreasing meat supply of food, with a steadily increasing population, is a permanent tendency. That likewise it will become more and more accentuated as time goes on, with the natural results of still higher prices of meat, and constantly increasing importations. To such an extent has this impression gained credence, that it has been seriously proposed that ultimately we may have to use horse flesh for food, as well as domesticate certain species of wild animals for the same purpose.

THE FACTS IN THE CASE.

Let us examine what at first seem undeniably, unpalatable facts. The accompanying diagrams give the actual number of cattle, milch cows, sheep and hogs in this country since 1890, also the number of cattle per 100 of population since 1850. (See Charts I and IV.)

The figures are taken from the Year Book of the Department of Agriculture, and are corrected at census dates 1890, 1900 and 1910 by Bureau of Census Statistics. The corrections for 1900 show a wide discrepancy between the estimated figures in 1899 and the census statistics of 1900, thus indicating that the estimated figures between 1890 and 1900 were below actual. Between 1900 and 1912 the figures are evidently in close correspondence with actual. These charts indicate clearly a series of ups and downs rather than a steady tendency to decrease. While it is true that population has increased steadily during this series of years, yet it is equally true that the number of cattle per 100 of population is practically the same now as in 1870, and this after all is the crux of the situation. The figures of census dates only are used in this latter chart.

CAUSES OF DECREASE.

The causes of the decrease in recent years are quite numerous and their operations obvious. Stated in the order of their importance they are as follows:

The great grazing ranges in this country lie principally between the 100 degrees and 110 degrees meridians of longitude, and within these limits are the great majority of herds, both of sheep and cattle. This section of our country, from the Mexican border to the Canadian line, is, with some local exceptions, of semi-arid nature. The native grasses are both hardy and nutritious, and under favorable conditions furnish feed for stock nearly all the year around in most sections. Until within the last twenty-five years the land in these sections had little value save for grazing purposes. The growing knowledge and practice of dry farming, the spread of irrigation, the increasing cultivation of such drought-resisting plants as Kafir corn, Milo maize, feterita and alfalfa, and the ceaseless teaching of intensive and scientific agriculture is steadily restricting the area which it is possible to profitably devote to grazing.

It is estimated that on the average the steer requires about 25 acres annually for grazing, since the native grass is often thin and scanty in its growth. It is obvious, therefore, that when for any reason the land becomes susceptible of cultivation, it also becomes much too valuable for grazing. The agricultural advance promises to go still further, as dry farming develops and as irrigation projects increase, but finally there will be reached that irreducible minimum of grazing land where rainfall is not sufficient even for dry farming, and where water is not available for irrigation. It will be a much circumscribed area compared with that formerly in use for stock raising, and it is evident that the answer as to an increased food supply of meat must be sought elsewhere.

Within the past decade unfavorable weather has been a serious factor. There have been seasons of protracted summer heat and drought where both water and grass practically dried up, and sheep and cattle in the Southwest perished by hundreds of thousands. Following three disastrous summers came winters of almost unparalleled severity, accompanied by deep snows and destructive blizzards. In some sections of the West and Northwest the losses ran from 25 to 50 per cent of the entire herds. While these weather cataclysms in a certain sense were temporary causes of reductions in the number of cattle and sheep, yet the experience of weather cycles indicates that, at least at long intervals, they must be reckoned with as certain, though irregularly recurring factors.

A further cause for decrease in cattle was the shortage in crops in many sections during the hot, dry summers and falls of 1909, 1910, 1911 and 1913. Many farmers found themselves financially unable to carry their stock through the winter because of high-priced feed, so the stock was rushed to market in great numbers.

In the case of hogs the principal causes of shortage are the high prices of feed during the four drought years named, and most serious of all, the destructive ravages of hog cholera during the past few years in the West, Northwest, Central West and South. There are other causes contributing to the general decrease in live stock, but they are not of such moment as those already recited, nor are their operations so clearly seen.

BEARING OF IMPORT AND EXPORT STATISTICS.

It is held that the story of increasing imports and decreasing exports indicates plainly that food exhaustion in meat supplies which is said to be so imminent. The force of this argument is based largely on the statistics of a few recent years. Let us go back to 1900 and see what the figures indicate as shown by the accompanying charts. (See Charts II, III, V.)

Let us also consult the export figures of some leading packing house products. (See Chart VI.)

If all the charts be considered through a long series of years they appear largely as fluctuations, but through them in general, more especially as relates to beef and mutton products, there appears a general tendency of exports to decrease and of imports to increase. If considered only from the viewpoint of the past few years, both of these tendencies appear increasingly accentuated. The statistics of 1913 only confirm still more these tendencies. Fairly stated, the facts are that from all points of view the domestic meat supply of food at present is decreasing not only actually, but also in proportion to the growth of population.

THE REMEDIES.

We naturally turn to foreign cattle and sheep raising countries as the easiest solution of our difficulties. They are principally Argentina, Australia, Canada, Brazil and Mexico. In each, with the possible exception of Australia, we find the same problem that confronts us, and that save for a comparatively brief period of a few years we are likely to lean on a broken reed. Statistics at present concerning Mexico are practically valueless, but the supply of cattle there available for our needs is extremely small. Moreover, the disturbed condition of the country is such as to preclude any hope of relief in that quarter for some time to come. The number of cattle in Canada is not great, nor is it liable to be so in the near future because of the extreme northern latitudes. With Canada, as with us, there is the same story of grazing ranges being converted to agricultural purposes, and of population growing faster than cattle.

Equally is this true of Argentina, where the supply of cattle is at a standstill, with agriculture steadily usurping grazing ranges, and with a population growing in greater ratio than our own. Already the limit of possible supply from Argentina seems to have been reached and passed as is evidenced by the decrease of 25 per cent in exports of frozen meats in 1913 as compared with 1912. The story of Brazil is that of a decrease in cattle supply in the same ratio as that of the increase in population. While the numbers of cattle in Australia and New Zealand show a large percentage of increase in the past ten years, the totals are not great, and the population in each country grows apace.

Against these discouraging facts are the great numbers of sheep available for food in Australia, New Zealand and Uruguay. Their principal purpose, however, is that of supplying wool, and a different use for them would mean not only a radical change in a great industry, but

CHART I—HOGS, SHEEP AND CATTLE IN THE UNITED STATES.

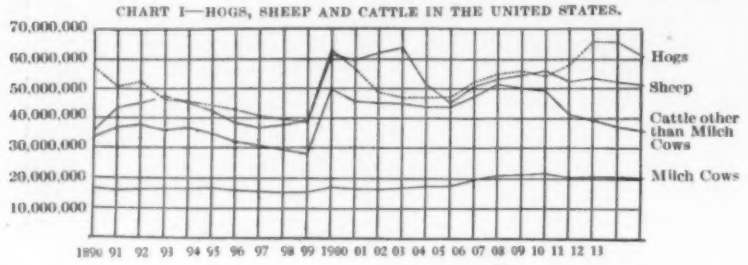


CHART II—SHEEP—IMPORTS AND EXPORTS.

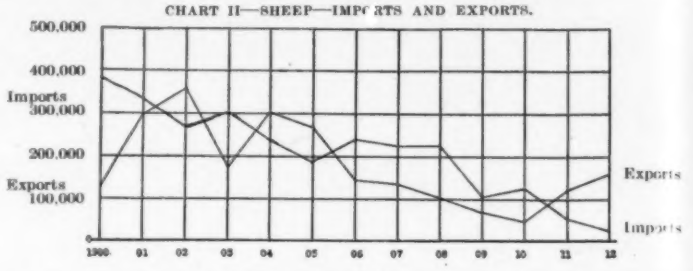


CHART III—HOGS—EXPORTS.

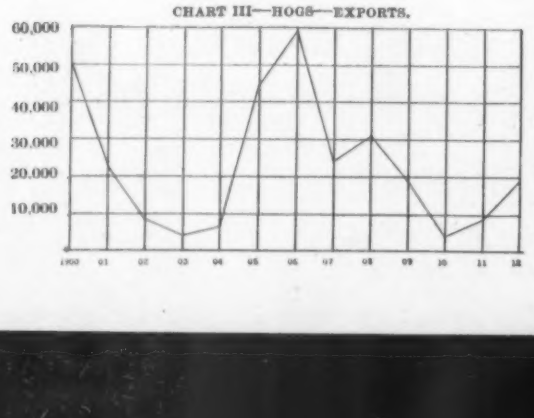


CHART IV—CATTLE IN THE UNITED STATES PER 100 OF POPULATION (NOT INCLUDING MILCH COWS).

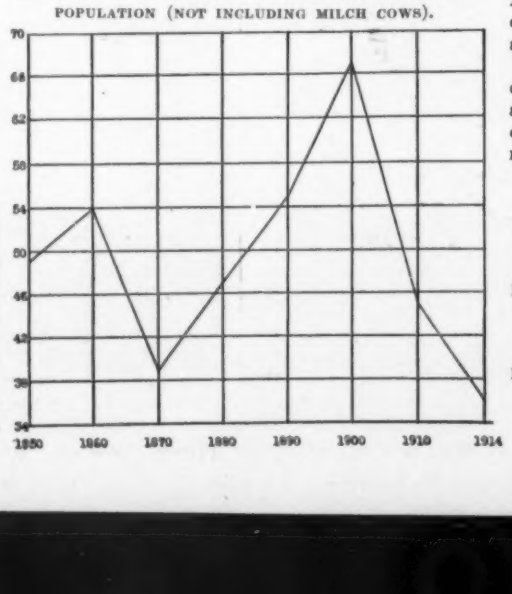
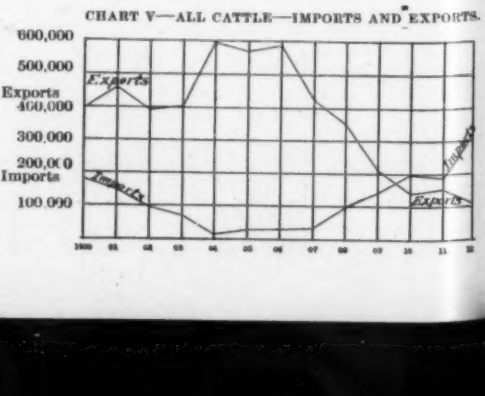


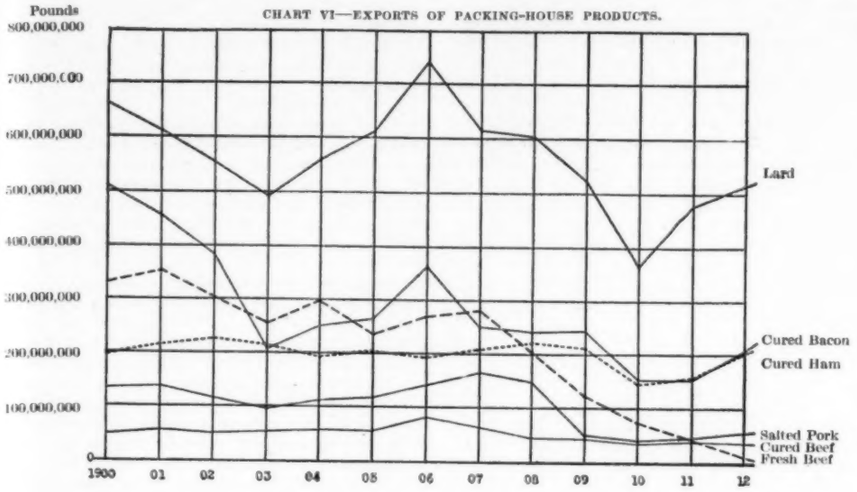
CHART V—ALL CATTLE—IMPORTS AND EXPORTS.



* Bulletin 88, dated March 30th, 1914, issued by the United States Chamber of Commerce. See also Bulletin 68 of January 2nd, 1914, and Bulletin 84 of March 9th, 1914.

a still greater change in the eating habits of our people. All statistics indicate, however, that we are becoming more and more a mutton eating nation. It largely resolves itself into the statement as to which is the more profitable, sheep raising principally for wool, and incidentally for food, or principally for food and incidentally for wool. It is to be noted also that sheep raising in Australia is subject to the vicissitudes and cataclysm of a climate where fierce heats and prolonged droughts

CHART VI—EXPORTS OF PACKING-HOUSE PRODUCTS.



of two and three years' duration deplete the flocks by many millions. This survey of the foreign field, therefore, indicates that we must look to domestic sources for any permanent relief in the future.

DOMESTIC RESOURCES.

A careful investigation reveals the fact that the cattle industry is undergoing a profound and far-reaching evolution, and that the great grazing ranges of the past will be in the future only one of the principal sources of supply. The Panhandle of Texas is an example of one of the new and important sources of future supply. This country, the Llano Estacado or Staked Plains of our boyhood maps, has a total area of about 25,000 square miles, and is an elevated plain of somewhat limited rainfall and a naturally fertile soil. Underneath almost the entire surface, at depths varying from 50 to 250 feet, is an apparently unfailing supply of water, pumped at a small cost by windmills, which everywhere dot the landscape. The country is fast changing from vast grazing ranges to a number of small stock farms where water for irrigation, when needed, is abundant for the growing of such hardy, rough plants for stock feed as Milo maize, Kafir corn, cow peas, and also alfalfa. The comparatively small size of these farms renders it possible to protect the live stock against the recurring winter blizzards which in the past have wrought such destruction to the herds.

The apparent tendency is not only toward better breeds and higher quality of cattle, but likewise toward a greater total number, probably during the next decade, than when the Panhandle plains were merely vast ranches. The steadily growing irrigation areas are furnishing another solution—in portions of Arizona, New Mexico, South Texas, Western Kansas, in fact, in many portions of the semi-arid sections of the West and Southwest, alfalfa is being grown by irrigation in increasing quantities. It has been found to be a cheap and nutritious food for both cattle and hogs, and a dependable crop, even under the stress of severe and prolonged drought. Its cultivation largely presupposes and demands the raising of cattle, and the dairy industry as a means of disposing of the product.

In that debatable region in Western Oklahoma, Western Kansas, Eastern Colorado and Western Nebraska, where seasons of sufficient rainfall alternate with those of serious deficiency in precipitation, not only the ways of dry farming in producing grain and fodder foods for man and beast, but likewise the steadily increasing cultivation of the sorghum grains (Milo maize, Kafir corn and feterita) are furnishing the essentials for dairy farming and stock raising. These sorghum grains are hardy plants that can be depended upon for fair yields even under the stress of long-continued heat and drought. The acreage planted in them grows steadily each year, and their cultivation and the raising of cattle are almost synonymous terms.

In portions of Oklahoma the bankers require of farmers to whom they loan money that for each head of live stock there shall be the necessary acreage of sorghum grains or of cow peas. In the States farther east where the rainfall is of more orderly and constitutional nature, the raising of stock on the farms is becoming not only a matter of direct profit, but one of the essentials of modern up-to-date farm management. It has been estimated that cattle and hogs return to the soil in natural fertilizers about 75 per cent of the value of the food they consume. It is one of the truisms of economics that the high price of any article greatly stimulates the supply, and this is naturally what may be expected to steadily increase the raising of stock on the farms.

THE SOUTHERN STATES.

The promise of the greatest new source of supply in the future comes from the Southern States. Curiously enough, this seems largely due to the story of two insignificant but malignant insects, the Texas fever tick and the cotton boll-weevil. The invasion in 1892 of the cotton fields of the South by the boll-weevil from Mexico seemed at first a calamity of the most disastrous and far-reaching import. It is now clearly seen, however, to be that needed impulse of dire necessity which alone could bring about the evolution of the South from the provincialism of a one-crop country to that diversification of production which marks every progressive agricultural people. The farmers of the South were forced by the stress of misfortune to raise food for the sustenance of themselves and their live stock because of their greatly reduced revenues from cotton. This erstwhile measure of necessity is fast crystallizing into a habit, until to-day the Southern States raise nearly one third of the total corn production, as well as growing more alfalfa year by year. Now that sufficient food for live stock is being provided, there remains but one more obstacle to prevent the South from becoming the ideal cattle section of the country, because of an equable climate, the possibility of grazing all the year around and freedom alike from devastating blizzards and destructive droughts.

That obstacle is the Texas fever tick, which for generations made cattle raising in the South impossible in any large way as a profitable pursuit. In 1906 the Federal Government and the various State authorities joined hands in a systematic campaign for the eradication of this pest by means of strictly enforced quarantine regulations and simple remedies of spraying and dipping the infected cattle. At the present time about one fifth of the area originally infested has been freed of the tick, and it is only a question of comparatively few years when the entire South will be relieved from the pest.

The outlook for a great increase in the number of sheep in the next few years is not so encouraging. Few of the factors mentioned as tending to increase the number of cattle are likely to operate in the same measure toward adding to the number of sheep. Sheep in large numbers are peculiarly the product of a primitive and thinly-settled country, and we shall have to reverse entirely our present methods if we are to depend upon the farm for our meat supply of sheep, though there are signs of an obvious tendency in that direction. Sheep are raised principally for their wool, and this is only economical when done in large numbers. Much, therefore, will depend upon whether it is found profitable to raise sheep and lambs for meat supply, with wool only as a by-product.

The story of hogs offers the greatest promise of all live stock for a large increase in our meat supply. They are peculiarly the product of small farms and a settled community, and the forces that tend to make cattle raising more difficult render the raising of hogs easier and more profitable. With the gradual abandonment of the old-fashioned plan of penning them up, they are becoming more valuable to the farmer in fertilizing the soil. The dread hog cholera that largely accounts for their reduced numbers, is gradually abating its ravages, because of greater observance of sanitary precautions and the increasing use and efficiency of hog cholera serum. We have rather more than one third of the world's supply of hogs, and raise about 80 per cent of all the corn produced. Neither of these proportions are likely to lessen in the coming years, especially as to corn, which is a thing not only of soil, but likewise of latitude, and can be grown successfully in large quantities only within certain comparatively narrow limits.

None of the other great continents combine all the requisites for corn production on so extensive a scale as North America. Corn growing and hog raising are almost synonymous terms in American farming. Moreover, the supply of hogs increases very rapidly under favorable conditions, and the outlook is for a large and steady increase in the future and a resumption of our best export activities in this direction.

Government statistics and the reports of competent observers alike tell the story of a slow but steady growth in the dairy industry in all sections of the Union. Not only is it proving profitable, but it adds ultimately, though incidentally, to our meat supply.

Another source of supply is the poultry industry, which is advancing in importance in all sections. The decade from 1899 to 1909 showed an increase in all fowls of from 250,000,000 to 295,000,000 fowls, or about 20 per cent. The increase was entirely in chickens, since the number of turkeys, ducks and geese declined.

CONCLUSIONS.

Such statistics as are available indicate clearly a decline *per capita* in consumption of meat as food. Nor is this altogether due to the high price. In fact, the eating habits of the people have altered materially within the past score of years. We have grown much more omnivorous and cosmopolitan in our tastes, and both common sense and experience have taught the hygienic value of a varied diet.

Vegetarianism has undoubtedly made headway. Food faddists are as numerous as the sands of the sea, and they all have following. It is a matter both of figures and of common observation that we are much larger consumers of fruits, vegetables and nuts than formerly. The American breakfast is no longer a matter of beefsteaks, but rather a light repast of fruit, cereals, and bacon and eggs. Meanwhile the heavy midday dinner has largely given place to a light lunch. In proportion to the growth of our population, we shall no longer need the same proportionate supply of meat as in the days of yore.

While hog and chicken supplies in the future will probably multiply rapidly, yet the creation of new cattle is a thing of slow growth. It will probably be from five to ten years, under favorable conditions, before we again reach a satisfactory normal in the numbers of cattle. Still there is every reason to believe that we are near the bottom of the hill. In spite of that, the price of beef may not revert to the low figures of the past, owing to the increased cost of raising cattle on the farm as compared with the ranch. Also because such reduction is not likely to be true any more of beef than of any other staple commodity, since in general the solution of the cost of high living seems to be not alone in reduction in the price of things, but equally an increase in the general purchasing power of the consumer.

The story of human experience is that readjustments of this nature are apt to be upward in their character as well as downward.

An impartial and careful survey of the field, therefore, fails to disclose any genuine cause for alarm, but rather that excessively high prices and declining supplies are but temporary and passing phases of an economic problem, of whose satisfactory solution there can be no reasonable doubt.

The Blue Hill Meteorological Observatory was bequeathed by its founder, the late A. Lawrence Rotch, to Harvard University, together with a fund making partial provision for its maintenance. Pending formal transfer to the university in March, 1913, all costs of maintenance were defrayed by Mrs. Rotch. All regular observations have been continued, and now cover a period of 28 years; normals for a 25-year period have been prepared and will soon be published. The temperature data of the observatory and its auxiliary stations are to be utilized in studies of frost protection. As Blue Hill was a pioneer institution in the use of kites for meteorological purposes, it is interesting to note that under the new *régime* these will probably be replaced by sounding balloons. The last kite flight made at the observatory, in March, 1913, narrowly escaped having tragic results. A flash of lightning melted a mile of the kite wire, damaged the reel and shocked two of the observers, one severely. Prof. A. G. McAdie, late of the U. S. Weather Bureau, assumed charge of the observatory October 1st, 1913.

A New Altitude Record.—A new altitude record of 12,303 feet for a flight with three passengers was established on March 20th at Johannisthal by Robert Thelen. This beats Garaix' record of 10,890 feet, which was made on March 2nd.

Progress in Wireless Telephony*

Freedom from Wave Distortion an Advantage Over Ordinary Telephony

By Prof. J. A. Fleming

THE attention of telephonic engineers has of late years been very closely directed to the improvement of the line wire in ordinary telephony. Apart from the imperfections of the telephone transmitter and receiver, *per se*, a very considerable effect is produced on the transmitted speech by the line itself if it is at all long. This action, from an electrical point of view, consists in the distortion of the wave form of the current as it travels along the cable, and its rapid attenuation or diminution in amplitude.

When speech is uttered to the mouthpiece of the transmitter, the current flowing into the line is modulated in a complicated manner, but this variation in virtue of Fourier's theorem can be analyzed into the sum of a number of currents of simple harmonic or sine wave form placed in certain relative phases and having certain amplitudes. The velocity W, with which any simple harmonic current travels along a cable having a resistance R ohms, an inductance of L henrys, a capacity of C farads, and a dielectric leakance of S mhos per unit of length, provided that the quantities R/pL and S/pC are small compared with unity, can easily be shown to be expressed by the formula:

$$W = \frac{1}{\sqrt{CL}} \frac{1}{\sqrt{1 + \frac{1}{p^2}\left(\frac{R}{2L} - \frac{S}{2C}\right)^2}}$$

where $p = 2\pi$ times the frequency.

Accordingly, the greater the frequency, the greater will be the wave velocity. In other words, short waves travel faster than long. The short waves, having also the least energy, attenuate most rapidly.

The result of this is that in the case of telephony along wires the different harmonic constituents of the current get out of step, and degrade unequally. Hence the wave form, and the quality of the received sound, is altered after the wave has traveled a certain distance along the wire or cable. The result is to diminish the loudness and reduce the clearness of the speech heard. Therefore, beyond a certain distance the articulate sound becomes unintelligible.

On the other hand, it is well known that the velocity of electromagnetic waves through space is independent of the wave length, and there is, therefore, in this respect a marked difference between the transmission of electromagnetic waves guided along wires and free electromagnetic waves diverging through space. As soon as the telephonic or aural method of receiving Morse signals in wireless telegraphy was substituted for the method of employing some form of coherer as a relay to actuate a Morse inker printing them in *dot* and *dash* on paper tape, the suggestion was made that it might be possible to transmit articulate speech by space electromagnetic waves, and not merely Morse signals composed of long and short sounds; and hence to conduct a wireless or lineless telephony.

It was at once recognized that before this could be done it would be necessary to provide a generator of electromagnetic waves giving truly continuous waves, and not merely intermittent groups or trains of rapidly decadent waves. The discovery of the power of the continuous current arc between carbon electrodes to create high-frequency oscillations in a condenser circuit connected between the carbons, held out hopes of making such a generator. It was not, however, until Poulsen discovered the peculiar properties of an electric arc formed in hydrogen or coal gas to enable very high-frequency oscillations to be so generated that progress began to be made. The Poulsen arc-generator consists, as is well known, of a direct-current arc formed with an electromotive force of about 500 volts between a carbon and a copper electrode in an atmosphere of hydrogen or coal gas. A strong

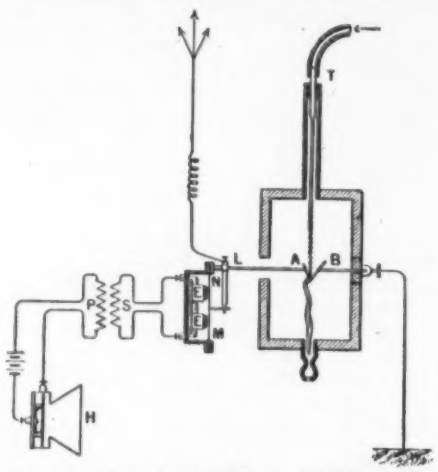


Fig. 1.—The liquid microphone of Dr. J. Vanni.

transverse magnetic field is also applied to the arc. An inductive circuit, consisting of a coil of wire having in series with it a capacity, the capacity and inductance being so adjusted that the natural frequency of this oscillation circuit is not less than about 50,000, or preferably much higher, even up to 250,000, is then connected between the carbon and copper electrodes. Powerful continuous electric oscillations are then set up in this condenser circuit. These oscillations can be made to set up similar oscillations in an open radiative circuit or antenna, which is inductively connected with the condenser circuit, as in the case of an ordinary wireless telegraph transmitter.

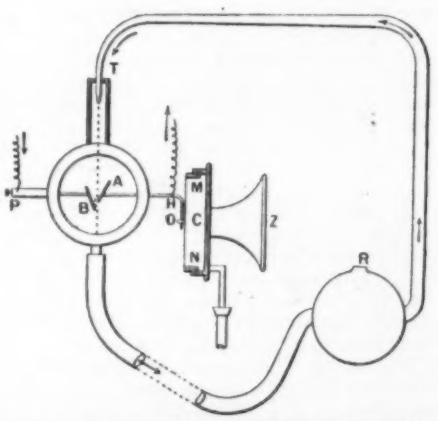


Fig. 2.—Arrangements for circulating the liquid by a rotary pump R in Vanni's microphone.

In this manner, continuous or uninterrupted electric waves of a wave length which is anything between 1 and 4 or 5 miles, can be radiated from the aerial wire. The reason the hydrogen or coal gas is effective in enabling the arc to create more powerful high-frequency oscillations is that it increases the steepness of the characteristic or volt-ampere curve of the arc, and hence increases the energy which is conveyed to the condenser at each oscillation.

To transmit speech we have then to modify the amplitude of these radiated continuous electric waves sent out from the sending station antenna in accordance with the wave form of the speaking voice. This is done usually by some form of carbon microphone inserted in the base of the sending station antenna. When the diaphragm of the microphone is acted upon by the voice, the carbon granules in it are more or less compressed, and the electrical resistance thereby altered. If then the high-frequency current in the antenna is made to pass through this microphone, the amplitude of the radiated continuous waves will be varied by making speech to the microphone, in such a way as to create waves upon waves, or to alter the wave amplitude in accordance with the wave form of the speaking voice.

At the receiving end, all the arrangements are identical with those required in wireless telegraphy when using a telephone and rectifier of some kind to receive audible Morse signals. The receiving antenna is coupled to a closed condenser circuit, and to the terminals of this condenser is attached a Bell receiving telephone in circuit with some oscillation rectifier, such as a crystal or constant detector, viz., carborundum, perikon, or zincite-chalcopyrite, or an ionized gas rectifier such as a Fleming glow-lamp valve. The telephone is then not affected by the rectified continuous oscillations *per se*, but it is affected by the variations in their amplitude produced by the microphone in the transmitter circuits.

Audible and intelligible speech can thus be reproduced at the receiving end. The limitations that present themselves in this transmission are wholly connected with the creation and modulation of the electric waves emitted by the sending station, and chiefly due to the difficulty of designing a microphone which can carry a sufficiently large current without heating. An additional trouble is that of devising a generator which shall be as simple and easily managed as that of a wireless telegraph plant.

As regards the microphone, most workers have employed a number of carbon microphones joined in parallel so as to enable a high-frequency antenna current of, say, 4 or 5 amperes to be passed through them without overheating any one. It is not easy, however, to divide the current equally between the microphones, or to keep them absolutely in step with each other. Another type is the liquid microphone of Majorana, and of Vanni. In Dr. Vanni's microphone a jet of water rendered slightly conducting by acid or salts is allowed to fall on a fixed inclined metal plate, B, and then bounces off on to another inclined metal plate, A, which is in mechanical or electrical connection with the diaphragm of a speaking mouthpiece (see Figs. 1 and 2). Speech, therefore, made to it sets the last-named plate vibrating, and thus breaks up and varies the resistance of the film or column of liquid connecting the two plates. Hence, if this liquid column is in the circuit of the transmitting antenna, any speech made to the diaphragm will vary the electrical resistance in the antenna circuit, and change in a similar manner the amplitude of the radiated electric waves.

W. Dubilier has also invented a water-cooled carbon granule microphone, the main diaphragm being moved by the current through a relay microphone to which the speech is actually made. This microphone can pass 700 watts with clear articulation (see Fig. 3). Then with regard to generators, a good many modifications of the arc generator have been produced. The Moretti arc consists of a copper tube kept supplied with water, and another copper rod is brought down so as to strike the arc against the water. When the arc is formed with a continuous current, and is also shunted as above described with a condenser inductive circuit, high-frequency oscillations are set up in the latter. There is a very rapid extinction and re-ignition of the arc, possibly due to some action like that in the Wehnelt interrupter. The writer of this article has also devised recently a new form of arc generator which requires no transverse magnetic field,

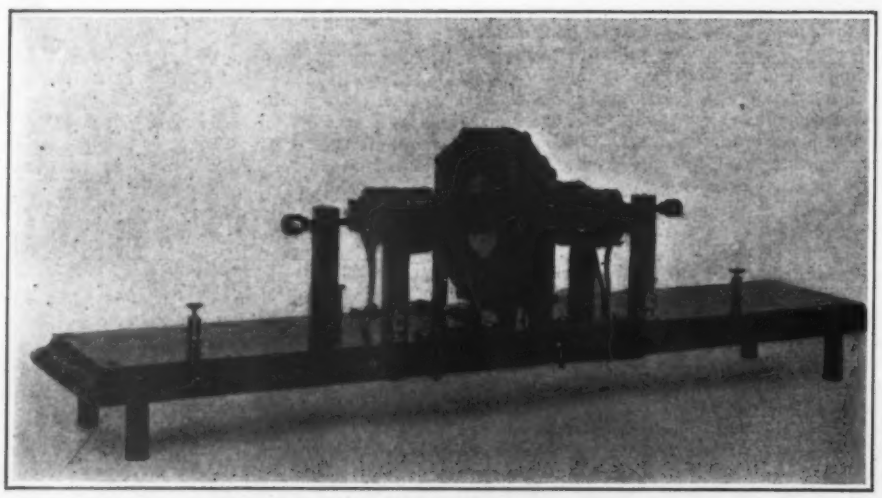


Fig. 3.—Dubilier water-cooled large current microphone.

* Reproduced from *Nature*.

nor supply of hydrogen or coal gas, as in the Poulsen apparatus. We have, then, in addition, the high-frequency alternator method of creating the oscillations. Fessenden experimented at one time very largely with such machines, devising a form of Mordey alternator which could give a frequency of 80,000 or 100,000. The invention by R. Goldschmidt of a means of multiplying frequency by means of a rotating field alternator made a new departure. By this machine high-frequency continuous oscillations are mechanically created, and their amplitude can be controlled by a microphone placed in the exciting circuit of the machine, so that it is not traversed by the main current.

Furthermore, we have the high speed, smooth disk generator of Mr. Marconi as a means of creating undamped oscillations, and, in addition, a telephonic transmitter has been invented by him which has not yet been described in detail, but was mentioned by him in a recent lecture in Rome. It is known that he has recently directed his attention closely to invention in connection with wireless telephony.

It is also possible to employ spark discharges of a very high spark-frequency, above the limit of audition, as a means of creating what are practically unintermittent oscillations, the separate trains of oscillations being practically in contact with each other. This method depends upon the self-extinguishing power of electric arcs produced between certain metals which are good conductors, such as aluminium and copper. If a pile of plates of these metals with very small air-gaps is built up, and a high electromotive force applied to it, discharges will take place, or small arcs which, when the discharger is shunted by a condenser, can generate high-frequency oscillations. By the aid of these appliances, their inventors and other workers have conducted wireless telephony up to a distance of 1,000 kilometers, or, say, 500 or 600 miles.

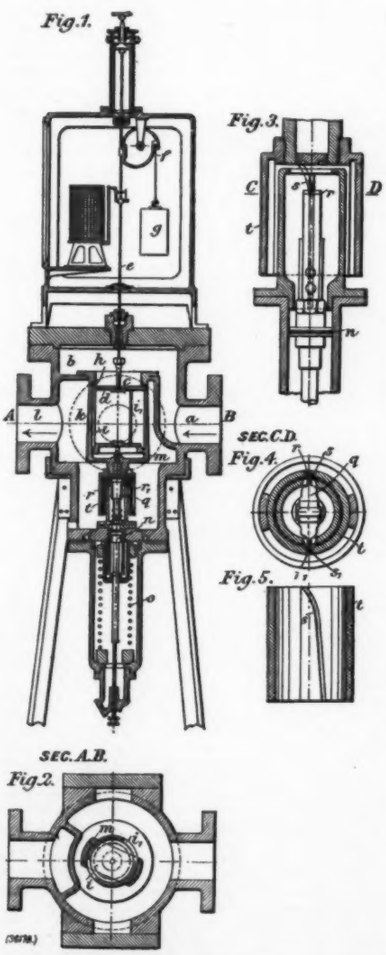
Thus, Dr. J. Vanni, working at Rome, and using a Moretti arc generator, his own liquid microphone, and a form of Fleming oscillation valve as a receiver, has transmitted and received articulate speech between Rome and the island of Ponza (120 kilometers), to Maddalena (260 kilometers), to Palermo (420 kilometers), to Vittoria (600 kilometers), and finally between Rome and Tripoli, a distance of 1,000 kilometers.

The speech is said to have been clear and singularly free from evidence of distortion of wave form. In addition to this, successful experiments in wireless telephony are said to have been conducted between Berlin and Vienna, a distance of 375 miles, by the Telefunken Company. The stations were the German high-power station at Nauen, to the west of Potsdam, and a receiving station on the roof of the Technological and Industrial Museum at Vienna. The experiments were so promising that it is expected much greater distances can be covered. A very inviting field of work seems to be opening out in connection with the alternator method of generation. With a suitably designed Goldschmidt high-frequency alternation, it is said that a small variation in the exciting current will produce very large variations in the amplitude of the radiated waves. Hence the microphone can be placed in the excitation circuit, and need only have a current-passing capacity of a few amperes to be able to modulate a radiation representing a very large horse-power. To transmit articulate speech across the Atlantic will necessitate the power of varying the amplitude of continuous wave radiation representing at least 50 or 100 horse-power. This must be done by means of some microphone which passes not more than, say, 10 amperes. These conditions are not impossible of attainment. Hence transatlantic wireless telephony may be said to be within the range of practical politics, while no improvements yet made in submarine telephonic cables hold out hope of being able within any reasonable time to speak through an Atlantic cable.

The subject of wireless telephony is, therefore, one which holds out much promise for future achievement, and it is not surprising that it is attracting the attention of some of the leading workers in radiotelegraphy.

A New Steam Meter

THE steam-meter which we illustrate in Figs. 1 to 6 has been tested by the steam-boilers supervision society of Aix-la-Chapelle, and recommended as a reliable direct-reading and recording instrument, and a decided improvement upon similar meters. The principle of the instrument is the following: The steam to be measured passes in the meter through two ports of rectangular section, the dimensions of which are varied by the conditions of the supply. The flowing steam depresses the counter-balanced disk of a valve, and the height or length of the rectangular port thus depends upon the quantity or weight of the steam to be measured; the steam pressure further acts on a piston which is guided by a cam-groove, and as this piston is depressed, the width or base of the rectangle is automatically altered. This is the chief feature of the instrument. The weight of steam flowing through the meter in kilogrammes per hour is $G = Fv\gamma$, where F is the combined area of the two rectangles, v the velocity, and γ the density of the steam, and the design of the meter is such that, if b is the base of the rectangle, the product $bv\gamma$ will remain constant for different steam pressures. One style may therefore register the steam weights though the pressures vary, and the actual steam consumption can be read off at any moment, and the total steam consumption easily be determined from the curve drawn on the squared card.



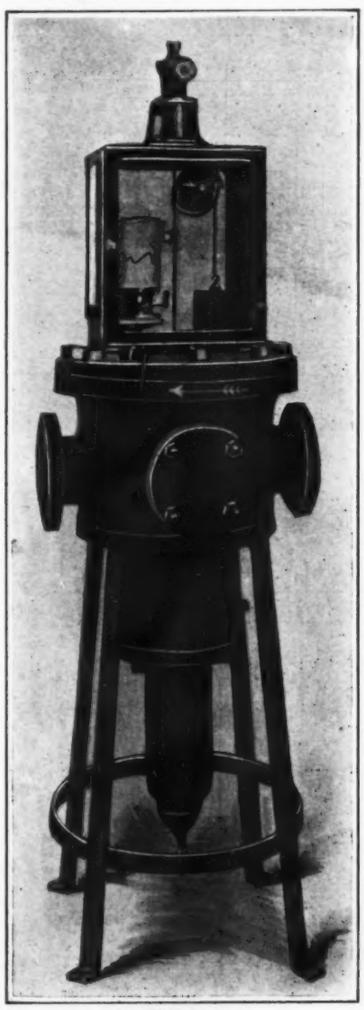
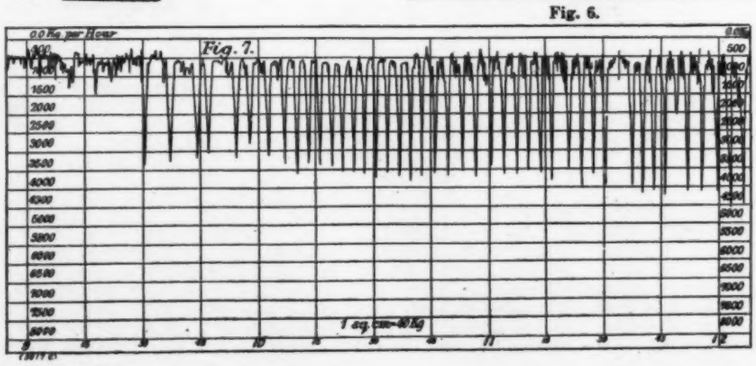


Fig. 6.



The engravings will explain the construction. The steam entering at a (Fig. 1) into the steam-chest b depresses the valve-disk d of the cylinder c; the wire e, attached to the disk d, passes over the pulley f and is loaded at g; the style is connected with the wire e. When the steam forces downward the disk d, and hence the style, the two rectangular ports i and i_1 of the cylinder c are opened to increasing heights; the steam then leaves the meter through the chamber k and the flanged pipe l. The width of the rectangular ports laid open depends upon the position of the ring-sleeve m, which is rotated by the aid of the devices illustrated in Figs. 3 to 5. The steam pressure urges the piston n downward against the pressure of the spiral spring o. When n descends, the crosshead q engages with its pins r and r_1 in the cam-groove of the drum t, which is rigidly connected with the ring-sleeve m; thus the sleeve is turned, and the width of the rectangular ports is narrowed. The shape of the cam-groove was determined by experiments. Some adjustment is required for the balancing load g of the valve disk d to keep the velocity of the steam constant, as long as the steam-pressure does not vary, though the quantity of steam passing through the meter increases as d descends and the open ports become longer. For this purpose, the pulley f (Fig. 1) has been pivoted eccentrically; the leverage at which the load g acts hence changes with the open length of the ports. Fig. 7 shows part of a record obtained at the Shamrock I. and II. colliery of the Hibernia Company, near Herne, Westphalia, with a double-cylinder shaft-sinking machine. Fig. 6 is a photograph of the instrument, which is now made in eight sizes, for steam-pipe connections from 25 millimeters up to 200 millimeters in diameter, and for steam consumptions from 300 kilogrammes to 20,000 kilogrammes per hour.

In the tests to which the instruments were submitted by the society above mentioned, the differences between the recorded consumptions and the weights of condensed steam fluctuated between the limits + 1 and — 2.9 per cent. The experiments were made at pressures ranging up to 12 atmospheres, and the report pointed out that even very small consumption values registered were fairly accurate. Priming water does not affect the records. The apparatus can also be used with superheated steam; in such cases the temperature has to be measured, and a correction may have to be made, since the density of steam depends upon its pressure and temperature. When the temperature is fairly steady, however, the calibration of the card can be adapted to that temperature.—*Engineering.*

Recent Discoveries in Physical Science—IV*

The Mechanism of Metallic Conduction of Electricity

By Prof. Sir J. J. Thomson, O.M., F.R.S.

Concluded from SCIENTIFIC AMERICAN SUPPLEMENT No. 2001, Page 299, May 9, 1914

THE mechanism in virtue of which a current circulates through a metallic conductor is nothing like so well understood as that by which electricity is able to flow through gases and through liquids. Indeed, if there is any truth in the view now held as to the nature of metallic conductivity, it is difficult to see how any satisfactory theory of the phenomenon could have been developed until quite recently. It is now, in fact, believed that the current through a metallic conductor is carried by those minute negatively-electrified particles of which the existence has been discovered only within the last few years. The history of the theory now held presents a striking example of the way in which apparently the most unpractical of studies can throw light on problems of the greatest practical interest. Those who have had to deal with the researches on the corpuscle were reproached at the time with being engaged in investigations having a merely theoretical value. Nevertheless, I am convinced that this reproach is mistaken even from the purely commercial and economic standpoint. The side lights gained by dealing with phenomena apparently unconnected in any way with practice often throw light on the theory of phenomena of the greatest industrial importance. Nothing could be worse for practical ends than that researches should be divided into two classes—the one "practical" and the other theoretical; the one to be supported and assisted from industrial and commercial resources, and the other to be carried on and financed by professors and universities.

I cannot see how the present view as to the nature of metallic conductivity could possibly have been arrived at by a "direct frontal attack." The negatively-electrified particles do not, in fact, obviously present themselves in the ordinary passage of a current through metals. Hence it would have been practically impossible to have got at the new view by even the most extensive experiments on metallic conductors.

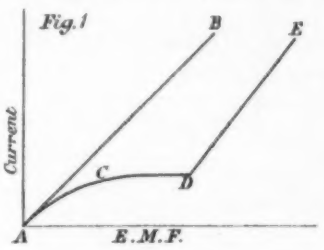
The early attempts to devise some theory of metallic conductivity were based on the analogy of conduction through liquids. The most noteworthy feature in electrolysis is that the passage of the current is accompanied by the motion of material particles; for example, when the fluid in question is water, hydrogen is transported and delivered at one side and oxygen at the other; and the process of electro-plating, again, depends essentially on the movement through the liquid of the atoms to be deposited. Many experiments have been made to determine if any corresponding transport of a metal accompanies the flow of a current through it. For example, two different metals have been placed in series end to end, and a very large current passed across the junction, to see whether there was any diffusion of the one metal into the other. Nothing of this kind could, however, be detected. A more promising plan of attack was next tried, a very strong current being passed through an alloy for a very long time, at the end of which an analysis of the metal was made. Here again, however, it was impossible to find that any change had been effected in the composition of the alloy, which remained the same at the end at which the current entered as at the end at which it left.

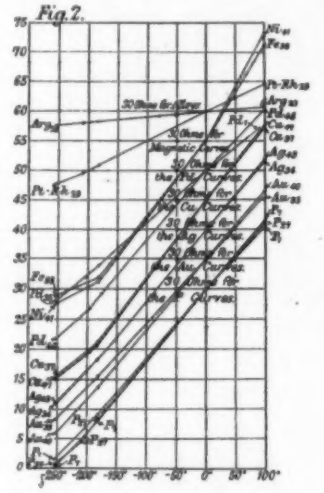
There is a remarkable difference between the laws of conductivity in metals and the laws regulating the passage of a current through a gas. In metals, Ohm's law governs entirely the connection between the current and the electromotive force. It is, of course, expressed by the relation:

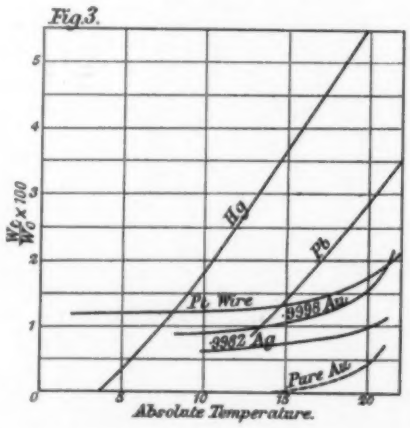
$$I = \frac{E}{R}$$

where I denotes the current, R the resistance of the conductor, and E the potential difference between the ends.

No other of the recognized natural laws has been so well verified as this. Very few experiments, indeed, can be made with the same accuracy as experiments on the resistance of metallic conductors, and all experiments have confirmed the law. If, therefore, current is plotted against electromotive force, the result is a straight line, as indicated by A B, Fig. 1. Apparently, so far as all but very recent experiments are concerned, the law would still hold, however large the current or however great the electromotive force, this result being on the ordinary view characteristic of the passage of a current through a metal. In the case of gases, however, it is only when the current is small that a straight-line law is followed. The curve soon turns round, as indicated by A C D, becoming parallel to the axis of electromotive force. A "saturation current" is thus obtained. In other words, a gas can only carry a certain current whatever the electromotive force applied—at least, up to a certain limit—after which a new process comes suddenly into being, and the current goes up as indicated by D E. As already stated, all the older experiments indicated that Ohm's law held for metals whatever the value of the current. There are, however, certain remarkable phenomena recently observed with metallic conductors which make it appear possible that, after all, there may be a maximum value to the current







which can be carried by a given piece of metal. This result, it must be confessed, however, is only arrived at by inference from some very recent experiments, which there has not yet been time to properly test.

There is one other important point connected with metallic conductivity to which I may refer. Is the value of the resistance the same for an alternating current as for a steady current? I do not refer here to certain well-known secondary effects. It is, in fact, common knowledge that the resistance of a wire is not the same for alternating as for steady currents, but this is merely due to the fact that the distribution of the current over the cross-section of the conductor is different in the two cases, the central core carrying less than its fair share of an alternating current. It is not to this secondary effect that I allude in asking whether the value of metallic resistance is affected by an alternating current. To this query the answer is that, if the alternations are rapid enough, the resistance certainly is greatly affected.

In fact, when light falls on a conductor, its energy is changed into heat, and we can calculate the depth to which light of a given wave-length penetrates into a conductor. This was first done by Maxwell, who computed to what depth light might penetrate into gold, and still retain an appreciable proportion of its original energy. This depth turned out to be quite small as compared with the thickness of gold leaf. Nevertheless, as a matter of fact, a considerable amount of light will penetrate such a leaf, the quantity being far more than would be possible if gold retained, for the very rapidly alternating electric forces accompanying light, its normal resistance for steady currents. A still more extreme case arises when Röntgen rays fall on a metal. These rays are now known to be light of excessively small wave-lengths, and with light of this kind no difference whatever is found to exist between insulators and conductors. Exposed to alternations of these excessively high frequencies, metals, therefore, do lose their conductivity, but it should be added that for this to ensue it is necessary to have reversal rates of billions per second.

Rubens, for example, has experimented with light in the infra-red, measuring what proportion is reflected from various metals. This he compared with the amount as calculated in terms of the resistance by Maxwell. Rubens found that until the wave-length of his light became less than 25μ the resistance was absolutely unaffected, the proportion of light reflected agreeing with that calculated from the normal resistance of the metal. Even with alternations as rapid as those corresponding to a wave-length of 4μ (about ten times the wave-length of sodium light), the departure between calculation and observation was only a few per cent. Hence the conductivity of a metal, though it cannot follow reversals of unlimited frequency, can nevertheless do so for alternations up to one billion per second.

Metals retain their conductivity whether in the liquid or in the solid state. This conductivity depends, however, not merely on the chemical nature of the metal, but also on the association of each molecule in close proximity to other molecules of the same kind. Prof. Strutt has shown that mercury vapor heated so as to be under a pressure of many atmospheres and at a corresponding density shows hardly a trace of conductivity. The ratio of the conductivity of the vapor to that of the liquid is, in fact, found to be a quantity altogether different from the ratio of the number of the molecules in a cubic centimeter of the gas and the number of molecules in a cubic centimeter of the liquid. Nevertheless, the conductivity of gases is by no means despicable, and mercury vapor does, in fact, possess a very considerable conductivity. Speaking generally, the conductivity of a rarefied gas is quite comparable with that of a liquid.

[To illustrate this, Prof. Thomson used a set of two coils placed in series and traversed by a current having a periodicity of a million per second. Each coil could, he said, be considered to be the primary of a transformer, and any conductor, placed within either, would constitute a secondary to that coil. Placing in the one coil a bulb containing rarefied gas, this gas glowed under the action of the secondary currents which then traversed it. On a similar bulb being placed in the other and more powerful coil, the first bulb A was extinguished, since so much of the energy of the current was absorbed by the currents excited in the second bulb at B. Replacing the bulb in B by a flask of water, the bulb in A continued in full excitement, showing that the conductivity of the water was so much less than that of a rarefied gas that the energy passing into A was hardly affected. Even when acid was added to the water, so as to bring up its conductivity to a maximum, its quenching effect on the bulb A was notably less than when the flask was replaced by the second exhausted bulb. Prof. Thomson also showed a variation of this experiment, in which an exhausted bulb immersed in acidulated water and placed in a strong alternating field, still glowed brightly under the water. A similar bulb fitted with a jacket, which could be exhausted by liquid air, was, on the other hand, quenched, when the pressure in the jacket was lowered sufficiently to render the residual gas a conductor. This again showed that the conductivity of a gas might exceed that of acidulated water. The high conductivity of the gas was due to the fact that when the pressure is sufficiently low the particles can move very easily under the electric forces acting upon them.]

A great amount of light on the nature of metallic conduction has been obtained by observing the effect of extreme cold on the conductivity of a metal. In this class of research, the pioneer is Sir James Dewar, some of whose results are plotted in Fig. 2. The curves in this diagram show that the resistance of a metal diminishes considerably when the temperature is lowered, but, as shown by the uppermost line in the diagram, the resistance of an alloy is relatively little affected.

With pure metals the law is, to speak roughly, that the resistance is proportional to the absolute temperature, but alloys behave quite differently. This result was arrived at many years ago by Matthiessen, who, in his experiments on conductivity, found that the resistance of

* Fourth and last of a series of lectures delivered at the Royal Institution.

an alloy cannot be calculated from the resistance of the constituent metals, being much greater than the resistance of either, and alloys had, he found, but a very small temperature coefficient. Matthiessen further found a certain law for the resistance of alloys, which he established throughout the ranges of temperature covered in his investigation, and this law has since been confirmed over the whole range of temperature now available.

Putting R_a as the observed resistance of the alloy, and R_c the resistance as calculated from the percentage composition, then throughout the whole range of his experiments Matthiessen found that $R_a = R_c + C$, where C is a constant independent of the temperature.

This law is a very important one, and the fact that C is large shows why the resistance of an alloy varies so little with changes of temperature. Since alloys do not follow the same law in this regard as pure metals, there must, in fact, be some other process than ordinary conductivity involved when a current traverses an alloy. Lord Rayleigh has shown from thermo-electric considerations that the resistance of an alloy should be greater than if calculated from its percentage composition. He considered the alloy as equivalent to a series of parallel plates, forming a series *A B A B*, etc. If in such case the current passed from *B* to *A*, the junction between the two metals would be cooled, while when it passed through the next junction from *A* to *B*, this junction would be warmed. A temperature difference would thus be produced, and the resultant thermo-electric effect would in each case be such as to resist the flow of the current. The corresponding back electromotive force would be proportional to the original, and undistinguishable from a resistance. The additional resistance thus produced is, however, insufficient to account for the whole of the observed increase in the resistance of alloys, and some recent work appears to indicate that the remainder is to be associated with the fact that metals have the property of forming "mixed crystals," the two components of an alloy not being laid down in the pure state side by side in the alloy, but each crystal of the one constituent contains a certain proportion of the other. The passage of electricity through such mixed crystals would follow quite a different law from that which applies to the passage through a pure metal. The result is that if any impurity existed in a metal, it would be impossible to get rid of its resistance no matter how much the temperature was lowered.

Kamerlingh Onnes has made some most important experiments in this connection, having observed the variation in the resistance of different metals when maintained at the temperature at which helium boils. His results are plotted in Fig. 3. In the case of gold, it will be seen that the line gradually becomes almost horizontal before the temperature reaches 8 degrees absolute. This residual resistance is attributed to impurities in the gold, and, if so, the resistance of pure gold would be obtained by subtracting this residual resistance from the results observed. In this way the dotted curve, shown at the right-hand corner, for pure gold is obtained. The most remarkable of the observations made are, however, those with pure mercury. As shown in the diagram, the resistance of mercury actually vanishes at an absolute temperature of 4 deg. Cent.—that is to say, its resistance is found to be less than one ten-thousand-millionth of its resistance at 0 deg. Cent. This is, I think, one of the most remarkable results in all physics. Kamerlingh Onnes has, in fact, obtained a body infinitely more conducting than any previously known substance. To get this result, he has taken extraordinary precautions in purifying his mercury. On, however, repeating the experiment with the grossly impure mercury used for silvering mirrors, the experimenter was, I imagine, rather disgusted to find that practically the same result was attained as with the mercury in the purification of which so much time had been expended.

In further experiments, Kamerlingh Onnes found that this state of "super-conductivity" could also be realized with lead and with tin, and the conclusion was that pure metals could be obtained in a condition in which they had no measurable resistance. As illustrating the difficulty of experiments of this kind, I may mention that when certain further experiments were suggested to Kamerlingh Onnes, an estimate of the cost involved led to the conclusion that it would be about as cheap to build a cruiser as to carry out the investigation proposed.

The state of super-conductivity only persists, it is found, if the current density lies below a certain critical value, which is some 100,000 amperes per square centimeter in the case of mercury, and a figure of the same order in the case of lead and of tin. So soon as this current density is exceeded then the absence of resistance disappears, and the potential difference needed to pass the current rises by leaps and bounds. It is possible that there is here a condition analogous to the saturation current in a gas, and that there really is a limit to the current a metal can carry in the normal way, and that if the current is increased beyond this saturation value some other effect comes in, involving an increase in the potential difference. In this connection, however, it is necessary to bear in mind the possibility of the heating effect of these very strong currents being sufficient to raise the temperature beyond the limit of the super-conductivity state. This point will, no doubt, receive very great attention, as the matter is one of extraordinary interest, and the results have to be interpreted by theory.

The first theory of metallic conduction based upon the action of negatively-electrified particles assumes that these are distributed freely among the molecules of the metal just as air might be round marbles piled in a box. When a conductor is acted on by an electromotive force these negative particles move along the lines of force, carrying the electricity with them, the amount transferred being proportional to the electromotive force applied.

In some respects, this theory fits in very satisfactorily and in particular it affords an explanation of one very remarkable phenomenon—viz., the proportionality between the conductivity of a metal for heat and for electricity. As shown by the annexed table, the ratio of the two conductivities is remarkably constant in all pure metals:

Metal	Electric Conductivity / Heat Conductivity
Copper	6.7×10^{10}
Silver	6.8×10^{10}
Gold	7.1×10^{10}
Nickel	7.0×10^{10}
Zinc	7.0×10^{10}
Lead	7.1×10^{10}
Iron	8.0×10^{10}
Constantin	11.0×10^{10}
Manganin	9.2×10^{10}

In the case of the two alloys constantin and manganin, there is, it will be seen, a large discrepancy. The proportionality between the electric and the heat conductivity follows at once on the hypothesis in question, if it is assumed that the negatively electrified particles also carry the heat by acquiring the temperature of the region in which they are, and transferring it to distant parts of the metals by diffusion. Not only does the proportionality of the two resistances follow from this hypothesis, but it gives nearly the exact value of the ratio.

There are, however, certain difficulties in the way of accepting this theory. For example, on this view the resistance of a metal should vanish at 0 degrees absolute, but actually the resistance of mercury vanishes at about 4 degrees absolute, at which, on the theory in question, its resistance should be 4/273 of its resistance of 0 deg. Cent., in place of one ten-thousand-millionth of it, as is actually found to be the case. To obviate this objection it has been suggested that, at very low temperatures, the kinetic theory of gases requires modification, this theory being that used in calculating the ratio of the resistance to electricity and to heat, it being assumed that the negative particles followed the gas laws. It is now suggested that at very low temperatures these laws no longer hold. In fact, one form of the "quantum" theory assumes that both the energy and the pressure of a body are finite, and not zero at 0 degrees absolute. Hence the velocity of the negative particles would not, on this view, be zero at 0 degrees absolute, but a constant, and they would therefore still exercise a pressure.

There is, however, another difficulty in the way of accepting the view that the negative particles are mixed up with the molecules of the metal. This is the difficulty of accounting for the observed value of the specific heat. If the negative particles were subject to the gas laws as assumed, they must, as the temperature of the metal rises, take up energy proportional to this temperature, and this energy would be added on to the specific heat of the metal molecules. It is possible to calculate the number of negative particles necessary to provide the actual conductivity of a metal, and this number proves to be such that the specific heat of metals should, if the hypothesis were true, be three or four times as great as it actually is found to be. This fact constitutes a very considerable difficulty in accepting the theory proposed.

Moreover, there is much doubt as to whether free negative particles do exist within a metal if that metal does not contain any gas occluded within it. In this room, Dr. Harker has shown how great is the liberation of negative particles from hot carbon. Yet Pring and Parker found that when the carbon is perfectly freed from all gas the emission of these particles falls to less than one billionth of its normal value. Again, it has recently been found that the liberation of negative particles from potassium, by the action of ultra-violet light, ceases when the potassium is perfectly freed from hydrogen.

I have myself advanced the view that in metals the negative particles, by which the current is transported, cannot be represented by the molecules of a gas diffused throughout the metal, but that each atom contains negative particles which are being continuously interchanged with neighboring atoms. When an electric field is applied, these particles tend more or less to arrange themselves on a sort of Grothuss chain, and I regard the current as conveyed by the corpuscles jumping across from one atom to the next. When no electric force is applied, this interchange still takes place; but as it is at random, there is no resultant current. On this view, the function of the electric force is to polarize the particles. This theory does not require the existence of free corpuscles, and therefore the specific heat of the metal is unaffected. Moreover, the disappearance of resistance at a temperature above 0 degree absolute can also be accounted for. The effect of temperature is, in fact, by the effects of the molecular agitation, to prevent the arrangement of the particles into line. As the temperature diminishes, the particles will more and more easily maintain themselves in line with the electric field, and when there is "no temperature," the smallest electric force will suffice for this. Moreover, there should be a maximum current, since the transport cannot be increased more when all the particles are polarized; so that on this view the current should reach a limiting value, and if it were wished to increase it, it would be necessary to call in some other effect which would result in a rise of the potential difference.

In conclusion, I may say that before long it is to be hoped that we shall be in a better position as to experimental evidence, and be able to regard the theory of metallic conduction with more confidence than is permissible for the present.

The Recent Motor Boat Races at Monaco

MONACO has recently been the scene of some flying and motor boat races. The flying events were not very successful, as only a few aviators had qualified. Some very interesting records, however, were established in the motor boat contests. The crafts comprised hydroplanes and propeller-gliders and so-called cruisers, that is to say, boats built to carry several passengers. England was represented by "Bat Boat II," a glider; Germany by two racers, the "Boncourt" and "Annette IV"; of the French boats the most noteworthy were the "Panhard Tellier," a 40-foot racer with 10-foot beam, carrying two 6-cylinder Panhard motors of 600 horse-power; and the racer "Despujols" 24 feet long and equipped with two Despujols motors of 400 horse-power each, which operate a pair of screws.

Among the events of special interest should be mentioned the one mile race. In the previous year the "Vonna" had established the record of 1 minute 26 1/5 seconds, corresponding to 41.6 nautical m. p. h. This record was broken this year by the big "Panhard Tellier" racer, which attained a speed of 46 9 miles per hour. But the "Despujols Sigma" far exceeded this, establishing the world's record with a speed of 53 miles per hour.

Another interesting event was the race for cruisers of the fourth and fifth class. The world's record in this class was held since 1910 by the 800 horse-power English boat "Ursula," which covered 50 kilometers (31.7 miles) in 43 minutes 25 seconds. The "Despujols Sigma" made the same distance in 42 minutes and 3 seconds.

In the race for the championship of the sea there were 13 boats entered. The victory went to the "Sigma V" (hull and motor Despujols) which reached the goal in 4 hours, 8 minutes and 38 seconds. The "J'en Veux" made the distance (108 sea miles) in 4 hours, 11 minutes and 55 seconds. The "Excelsior" being third.

Demand for More Universities in Germany

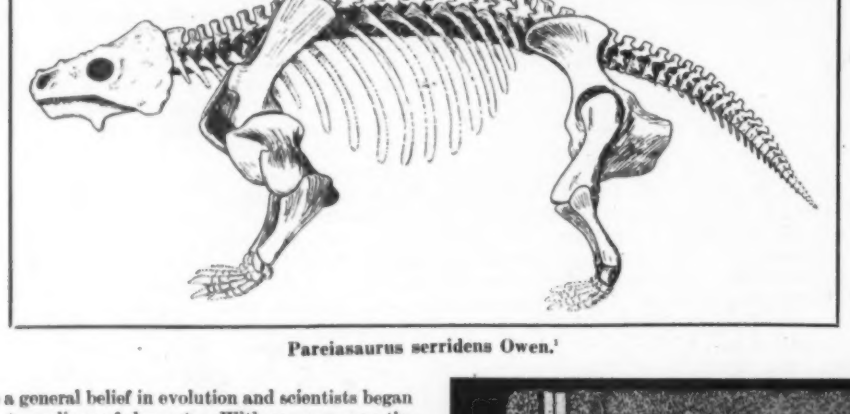
AN article in the *Westminster Gazette* by the Berlin correspondent of our contemporary, reveals a growing demand in Germany for more universities. It is alleged that existing universities are overcrowded owing chiefly to the invasion of foreign and of women students, and the more general need of university education for officials. The number of such institutions is smaller than it was a century ago. Cologne, Trier, Duisburg, Helmstedt, Wittenberg, Frankfurt-on-Oder, Mainz, Erfurt, Altdorf and Ingolstadt have all been university towns. Since the empire was founded the number of students has increased fourfold. In 1880 there were 30,000 students; in 1905, 42,000; and last year more than 60,000. There are 5,300 foreign and 3,500 women students, and about 4,000 non-student auditors. The agitation for new universities came to a head last year when Hamburg, Frankfurt-on-Main, Dresden, Posen, Cologne and some smaller towns proposed to establish universities. The impulse in some cases was the desire of existing special and technical high schools to expand into universities with full university status, but with a reduced number of faculties. The advocates of new universities complain that the universities have recognized with ill-will the increasing specialization of science; and that specialization is now hopelessly ahead of them. Some reformers want not only specialization within universities but specialization of the institutions themselves. Each university, while keeping its faculties and its general culture system, should aim at a predominant position in a particular branch of science; and should be specially well supplied with professorial chairs, seminaries, libraries and collections bearing on its specialty.—*Nature.*

South African Fossil Reptiles*

Fossils Excavated from the Blue Shales of South Africa Prove Reptiles to be the Ancestors of Mammals

By Prof. Robert Broom

PROBABLY no question is so interesting to biologists as the origin of mammals, and few questions are more interesting to the layman. Up to 1859 when Darwin published the "Origin of Species," very few worried much about the origin of anything. The prevailing belief was that somewhere about the year 4004 B. C. the Almighty created all animal forms just as we find them to-day. A few scientists had before this time come to the conclusion from their examination of the fossils found in the rocks that there were serious difficulties in the old view, and many attempts were made to harmonize the scientific facts with the old traditions, but for the most part those who held views differing from their fathers were cautious in expressing them. After 1859 the full and free discussion of the problems gradually led to a general belief in evolution and scientists began to try to trace lines of descent. With some groups the lines of evolution were fairly manifest, but with the warm-blooded animals the case presented the greatest difficulty. No other forms seemed at all nearly allied and while it was natural to assume that they must either have sprung from lizard-like reptiles or salamander-like amphibians, there was no clear evidence to decide the question.



Pareiasaurus serridens Owen.[1]

In 1876 Owen, in describing the fossil reptiles of South Africa, pointed out numerous mammal-like characters seen in them, and in 1880 definitely expressed the view that the primitive mammals living to-day in Australia are the direct descendants of a reptilian ancestor such as he had described. Huxley, on the other hand, favored the descent of the mammals from a salamander-like form, and the contest between those who believe them descended from amphibians and those who look on reptiles as the ancestors has been waged ever since—sometimes rather vigorously.

When Cope in 1880 studied the remarkable Pelycosaurs, fin-backed reptiles found in the old Permian rocks of New Mexico and Texas, he came to the conclusion that he had found, if not the mammalian ancestors, at least forms allied to them, and in this I believe he was quite correct.

Between 1888 and 1905 Prof. Osborn published a considerable number of papers dealing with the origin of mammals, in which he argued that the ancestor of the mammal was probably a member of that group of very mammal-like reptiles found in South Africa and called Cynodonts. This view of Osborn's seems at first sight opposed to that of Cope's, but in all probability both views were correct, the Pelycosaurs being a side branch from a direct line very near to the early mammalian ancestors, the Cynodonts being probably the immediate ancestors of the mammal.

Baur, who worked here in America and died some fifteen years ago, was in favor of the reptile origin. Seeley adopted a rather curious view. He believed that the egg-laying mammals came from reptiles, but that other mammals arose from amphibians. On the whole, the Germans have favored the amphibians as ancestors, while English opinion, although somewhat divided, has mainly been in support of the reptilian theory. The majority of Americans, doubtless influenced by Cope and Osborn, have always favored the descent of the mammals from a reptilian ancestor.

I became interested in the question in 1885, and practically resolved then that I would contribute what I could to the solution of the problem. In 1892 I went to Australia and spent some years in studying the egg-laying mammals and marsupials. In 1897 I went to South Africa and have been working in that region for the last seventeen years. In these seventeen years nearly every specimen that has been picked up there has passed through my hands.

We call our South African deposits the Karroo formation—naming it from the Karroo desert—and there is probably none in the world of greater interest. This formation is extensive, covering the greater part of the interior of Cape Colony, almost the whole of the Free State and much of the Transvaal, Basutoland and Natal, an aggregate area of 200,000 square miles. The formation is composed of bluish shales much like slate in color and of mudstones, and there is little doubt that it has been formed of the mud brought down into a large basin by a huge river, such as the Amazon. Besides being of great extent, this deposit is also of great thickness, in some parts probably as much as 10,000 feet thick.

If you look upon this area as a series of rocks 10,000 feet thick and 200,000 square miles in area, and imagine it the face of a book of the history of the world, you see that it is simply a matter of our turning over the pages. There is not another part of the world that will give the records so completely—a continuous record of the land animals of the world for about three million years. Sometimes we cannot read the record clearly, but we can make out most of it. This period is not only very fully recorded, but there is no period of the world's history so interesting, except the period when man came upon the earth. It is a period when crocodiles, lizards, turtles and reptiles appeared for the first time, and the study of the records shows us the warm-blooded four-footed forms in the process of evolution.

The greater part of the Karroo formation lies in the center of Cape Colony. This large area has a scanty rainfall of from five to fifteen inches in the year but, as most of the rainfall is due to thunder-storms during a short period, there are usually nine months in which no rain falls, and the vegetation is almost entirely composed of low Karroo bushes. The whole scenery is in many ways strikingly similar to that of Arizona. There are extensive plains that are almost dead level produced by the action of wind eroding exposed surfaces and filling up the hollows. Jutting out from the plains are the kopjes and mountains. These are preserved through being protected by sheets of igneous rock. In the plains, owing to the fact that almost the whole surface is covered with wind-blown dust, it is impossible to see any fossils except where the ground has been washed by a flood. On the sides of the hills in many places the shale is denuded of vegetation and exposed, and it is on these exposed slopes that most fossils are obtained. Unfortunately, if a slope is steep it is extremely difficult to excavate any specimen even if discovered, the best localities being gentle slopes and the beds of rivers.

The distribution of fossils is very uneven. In some

An American mammal-like reptile.[2]

Galepus jouberti Broom, one half natural size.[3]

* Reproduced from the American Museum *Journal*.

[1] A restoration of a skeleton founded on the specimen in the South African Museum. Though not a mammal-like reptile it resembles them in having powerful limbs and the body lifted off the ground. The skeleton is from 8 to 9 feet in length and stands about 3½ feet high.

[2] Incomplete skeleton of *Dimetrodon incisivus* Cope, as mounted in the American Museum of Natural History. This is one of the largest of the American primitive mammal-like reptiles. It was described by Cope, who correctly recognized its mammal-like affinities.

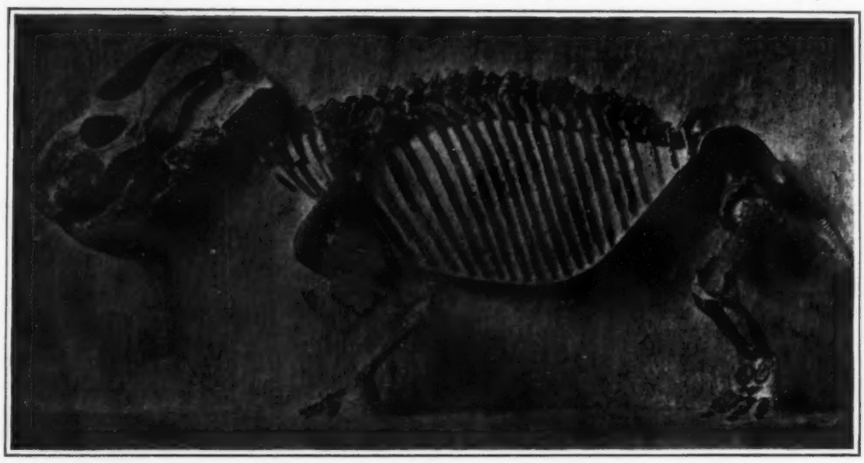
[3] A complete skeleton of a small member of the Dromasaurians, one of the earliest of the mammal-like reptiles. The head (at the left below) is folded back, so that in this photograph it is seen very obliquely, but with care all the rest of the skeleton may be easily traced.

Contrast in size among ancestors of mammals.[1]

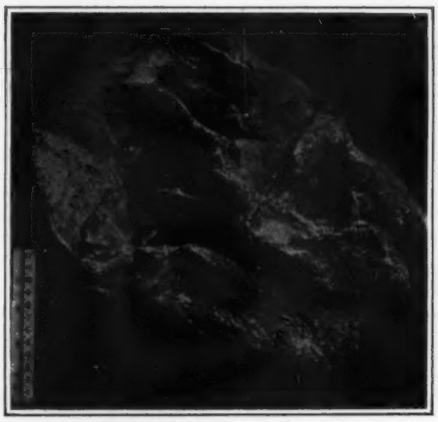
Relative size of allied South African reptiles.[2]

places one may travel and search over every slope of shale for forty miles without seeing a scrap of bone; in other places, sometimes in a small area of a few hundred square feet, a large number of specimens may be obtained. Bones are usually seen readily because their color is lighter than the shale. To many of the Dutch farmers and to members of their families, we are indebted for some of our best specimens, and even the Hottentot goatherds are often useful in spotting specimens while out on the hills watching their flocks.

The oldest animals we meet with in the Karroo formation in any number are of middle Permian age, shall we say of the year 18,000,000 B. C. These are of especial interest from the resemblance they bear to the American Permian reptiles from Texas and New Mexico. One of the largest and best-known animals is called *Pareiasaurus*. It is a large-limbed reptile, about 9 feet in length and standing about 3½ feet in height. In many points of its organization it shows affinities with the American reptile, *Diadectes*, of which a mounted skeleton is to be seen in the American Museum. Another group of animals contemporaneous with *Pareiasaurus* is the reptilian group of Dinocephalians. These also were large reptiles with very powerful limbs. Although herbivorous and having no remarkable specialization of the spines of the vertebræ, they are nevertheless



Almost complete skeleton of a mammal-like reptile.[4]



Endothiodon uniseries Owen.[5]

fairly closely allied to the very remarkable American fin-backed Pelycosaurs, of which skeletons are to be seen in the American Museum.

One of the most striking peculiarities of the Karroo reptiles is that almost all agree with *Pareiasaurus* and the Dinocephalians in having powerfully developed limbs. How these have been evolved is a matter of doubt, but there can be little question that it was this strengthening and lengthening of the limbs that started the evolution which ultimately resulted in the formation of the warm-blooded mammals.

The best known, and in some respects the most remarkable, of the Karroo reptiles, belong to a group named by Owen, the Anomodonts, from their having horny beaks like the turtles or birds with, in addition, in many forms, a pair of large walrus-like tusks. The first specimen was discovered as far back as 1844, and was called *Dicynodon*, but although many skulls have been discovered only three or four fairly good skeletons have been found. In limbs, shoulder and pelvic girdles and essential structure of the skull and in the number of joints of the toes they strikingly resemble the mam-

[1] *Endothiodon whaitsi* Broom and *Emydops minor* Broom. The skull of the largest known form of *Endothiodon* and of the smallest known of the Anomodonts.

[2] *Dicynodon whaitsi* Broom and *Diictodon galeops* Broom. The skull of one of the largest forms of *Dicynodon* and of one of the smallest allied forms. This specimen of *Dicynodon whaitsi* is a female in which the tusk does not project, but it is present in the specimen deeply embedded in the bone. Formerly all those specimens of Dicynodont reptiles in which there was no manifest tusk were placed in the genus *Oudenodon*. *Oudenodon* was also placed by Owen in a distinct family. For years the question was debated by all workers on South African reptiles whether *Oudenodon* might not be the female of *Dicynodon*, and all have concluded that the evidence seemed rather to favor their being distinct forms. No known specimen of *Oudenodon* sufficiently resembled any known specimen of *Dicynodon* to be manifestly the female of that species. Within recent years, however, it has become quite certain that *Oudenodon* is the female of the tusked *Dicynodon*. In at least three species of *Dicynodon* we have a manifest series of tusked and tuskless specimens, and the same also occurs in other closely allied genera. In some species there is a rudimentary tusk, in others apparently no trace of tusk, while just possibly in some of the larger forms, such as *Dicynodon* (*Kannemeyeria*), most probably the female is also tusked. Exactly what the function of the tusk may have been is unknown. Many suggestions have been made which are manifestly incorrect. Pretty certainly the tusks have nothing to do with the procuring of food, as the females in which they are absent doubtless got on as satisfactorily. Probably they were in *Dicynodon*, at least, secondary sexual characters like the spur in the duck-billed platypus.

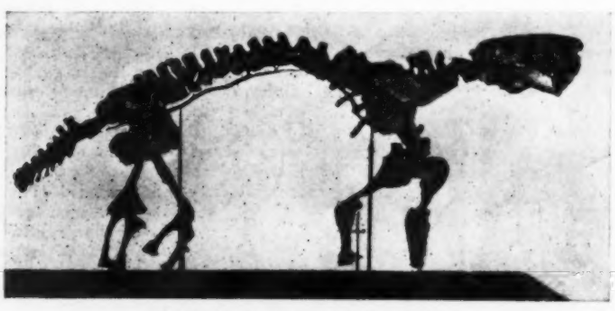
[3] *Endothiodon uniseries* Owen. One sixth natural size. The skeleton is slightly crushed, the limb bones especially being considerably flattened. This is the first nearly complete skeleton of an anomodont reptile that has been mounted and the attitude is probably very nearly correct. The toes of the hind feet are probably directed slightly outward, those of the front feet slightly inward. The resemblance of the attitude and the structure of the limbs and girdles, it will be observed, are strikingly like those of mammals, and even the skull when allowance is made for the remarkable specialization of the beak is not so very unmammal-like.

[4] A more perfect skull than that belonging to the mounted skeleton.

[5] This is one of the South African forms closely allied to the better-known Russian *Inostrancevia alexandri*.

[6] A photograph of a skeleton of one of the large mammal-like reptiles found fossil on the banks of the Dvina River in north Russia. The skeleton is of large size, the skull being about two feet in length and is extremely closely allied and perhaps identical with some forms found in South Africa.

Scymnognathus angusticeps Broom.[3]



Inostrancevia alexandri Amalitsky.[6]

mals, and although the curious development of the beak obscures the mammal-like character of the skull, it is essentially built on the mammalian plan, and there is little doubt that although the Anomodonts are a side offshoot from the mammalian stem, they are closely allied to the mammalian ancestor.

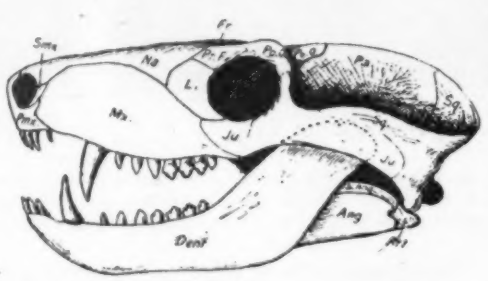
A form nearly allied to *Dicynodon* is called *Endothiodon*. It has no large tusk but a number of small teeth. Although much rarer than *Dicynodon*, fortunately an almost complete skeleton has been discovered which has recently been mounted in the Museum laboratories by Mr. Charles Falkenbach under my direction, and of which a photograph is given. The extremely mammal-like condition of the limbs is very manifest, and there is little doubt that the animal waddled about somewhat after the manner of the pigmy hippopotami of Liberia, seen at the New York Zoölogical Park. Attention may be called to the relatively enormous size of the skull and the curious way in which the long point of the lower jaw passes up into the groove in the upper.

We find many other mammal-like reptiles of which the Therocephalians, Dromasaurians and the Cynodonts are the most important. Although these insectivorous and carnivorous types are less mammal-like in some respects than the Anomodonts, they agree more closely with the mammals in the construction of the skull. They all have long, slender limbs adapted for running. The earlier members, such as the lower Therocephalians, have the number of toe joints as still found in the lizards and most reptiles, viz.: 2, 3, 4, 5, 3; but the Anomodonts, the lower Dromasaurians and the higher Cynodonts have the same number of joints in the toes as is retained in ourselves, viz.: 2, 3, 3, 3, 3. It is rather interesting to look at one's hand and realize that the fingers have all these joints because a remote ancestor took to walking with the feet under the body supporting it off the ground rather than with the feet to the side as in the lizards and crocodiles.

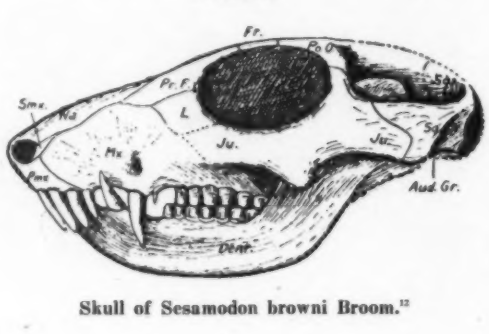
The Cynodonts occur in the Triassic formation and a few survive into the Jurassic. In most points of structure they are extremely mammal-like, and it is frequently impossible if the specimen is at all incomplete to say whether we are dealing with one of the Cynodonts or a mammal. The lower jaw is almost entirely formed by a large single bone, the posterior bones being small, and the bone on which the jaw hinges is also small, thus foreshadowing the mammalian condition, the dentary bone, the angular, articular and sur-angular being quite small, as is also the quadrate bone. The teeth are in most forms of a carnivorous type, composed of sharp incisors, long sharp canines and cusped molars, the cusps being almost exactly like those of the carnivorous mammals.

A couple of months ago I discovered that in the Cynodonts the incisors, canines and premolars are preceded by an earlier set exactly as in ourselves. It would probably be inappropriate to call them milk teeth, as it is very unlikely that the Cynodonts provided their young with milk, but there can be no doubt that the young had a first temporary set of front teeth like most mammals.

Skull of Bauria cynops Broom, about one half natural size.[10]



Skull of Nythosaurus larvatus Owen, slightly reduced.[11]



Skull of Sesamodon browni Broom.[12]

Besides solving the question of the origin of the mammals, the Karroo fossil beds have thrown some light on the origin of birds. There has been considerable discussion as to whether birds were derived from flying bat-like reptiles called pterodactyls or from the dinosaurs. Some have even gone so far as to derive the flying birds from the pterodactyls and the running birds, such as the ostrich, from the dinosaurs. Dr. Lucas is one of those who favors a double origin for the birds. Prof. Osborn some years ago argued in favor of the birds and dinosaurs having come from a common ancestor in Permian times. A few years ago I maintained, as the result of my studies on the development of the ostrich, that the ancestor of the bird, though not a dinosaur, was nearly a dinosaur, and that the bird and the carnivorous dinosaur were derived from a group of primitive dinosaur-like reptiles that were capable of running on their hind legs. A recent discovery in South Africa reveals just such a type as we required for the common ancestry of the birds and the dinosaurs, and this form is also not far removed from the ancestor of the pterodactyl. The birds, pterodactyls and carnivorous dinosaurs are all probably sprung from a small reptile such as the one recently discovered in South Africa and named by me *Euparkeria*.

Another interesting fact that seems to be brought out by our study of the South African fossil forms is that it was probably the development of the active Cynodonts that led to the development of the active reptiles such as *Euparkeria*. For possibly two million years the carnivorous mammal-like reptiles had an abundant supply of food in the form of the small Anomodonts. In lower Triassic times the smaller Anomodonts seem to have become extinct for some reason and the carnivorous forms had to obtain a new diet, which was probably a little lizard-like animal called *Procolophon*, and possibly other small reptiles of a similar type. It was possibly this new activity that gave rise to the Cynodonts. In upper Triassic times the Procolophons became extinct and the small Cynodonts were driven to attacking the more active types like *Euparkeria*. The rivalry between these forms resulted in the greatly increased activity of both, the active four-footed forms becoming the primitive mammals and those which run on their hind legs gave rise to the theropodous dinosaurs and the ancestral birds. The further evolution of the bird was doubtless the result of its taking to an arboreal habit and developing feathers.

[10] This is the most primitive of the very mammal-like reptiles belonging to the group of Cynodonts. The dentition, it will be observed, is like that of the mammal except in that the grinding teeth are simply little pegs not unlike those found in the armadillo.

[11] This is one of the most mammal-like of the reptiles belonging to the Cynodonts. Were it not for the composite character of the lower jaw it might readily be regarded as a mammal.

[12] This is another type of cynodont reptile which is in some respects more like the mammal than any other.

Effect of Electrical Engineering on Modern Industry*

As Steam Locomotives Revolutionized Material Traffic, Electric Transmission is Reforming Energy Distribution

By Charles P. Steinmetz, M.A., Ph.D., Professor of Electrophysics, Union College; Chief Consulting Engineer, General Electric Co.

To understand the reasons which enable electrical energy to compete successfully with other forms of energy, which are longer and more familiarly known, we have to look into its characteristics.

Electrical energy can be transported—or, as we usually call it, transmitted—economically over practically any distance. Mechanical energy can be transmitted over a limited distance only, by belt or rope drive, by compressed air, etc.; heat energy may be carried from a central steam-heating plant for some hundred feet with moderate efficiency; but there are only two forms of energy which can be transmitted over practically any distance—that is, which in the distance of transmission are limited only by the economical consideration of a source of energy nearer at hand: electrical energy and the chemical energy of fuel. These two forms of energy thus are the only competitors whenever energy is required at a place distant from any of Nature's stores of energy. Thus, when in the study of a problem of electric-power transmission we consider whether it is more economical to transmit power electrically from the water-power or the coal-mine, or generate the power by a steam plant at the place of demand, both really are transmission problems, and the question is whether it is more economical to carry energy electrically over the transmission-line, or to carry it chemically, as coal by the railroad-train or boat, from the source of energy supply to the place of energy demand where the energy is converted into the form required, as into mechanical energy by the electric motor or by steam-boiler and engine or turbine.

Electrical energy and chemical energy both share the simplicity and economy of transmission or transportation; but electrical energy is vastly superior in the ease, simplicity, and efficiency of conversion into any other form of energy, while the conversion of the chemical energy of fuel into other forms of energy is difficult, requiring complicated plants and skilled attendants, and is so limited in efficiency as to make the chemical energy of fuel unavailable for all but very restricted uses; heating, and the big, high-power steam-plant. Pressing the button turns on the electric light, and thereby starts conversion into radiating energy. With chemical energy as source, either special fuels are required—in the candle, kerosene-lamp—or a complex gas-plant. Closing the switch starts the motor, whether a small fan-motor, or a 1,000 horse-power motor supplying the water system of a city or driving the railroad-train. With fuel as source of energy, boiler-plant, steam-engine, or turbine, with its numerous auxiliaries, with skilled attendants, etc., are necessary, and the efficiency is low except in very large units. To appreciate the complexity of the conversion of the chemical energy of fuel, compared with the simplicity of electrical energy conversion, imagine the domestic fan-motor with coal as source of energy: a small steam-engine, with boiler and furnace, attached to the fan. To start the fan, we have to make a coal-fire, and raise steam to drive the engine. This illustrates how utterly unavailable the chemical energy of fuel is for general energy distribution. General energy distribution, therefore, may justly be said to date from the introduction of electric power.

Equally true is the reverse: the conversion of mechanical or other energy into electrical is simple and economical, while the conversion into chemical energy is not. Hence, one of the two large sources of Nature's energy, the water-power, was, before the days of electrical engineering, useless, except to a very limited extent, since the location of the water-power is rarely such that the energy could be used at its source. The water-powers thus have really been made available only by the development of electrical transmission.

Characteristic of electrical energy is that it can be concentrated to an energy density higher than any other form of energy, and results can thus be produced by it which no other form of energy can bring about, or things done directly by the brute force of energy, as we may say, which formerly had to be brought about in a roundabout way.

Thus iron can be reduced from its ores by the chemical energy of coal in the blast furnace, but aluminium and calcium cannot, as their chemical affinity is higher, and require the higher energy concentration available with electric power. Iron reduced in the blast-furnace combines with carbon to cast iron. So calcium combines with carbon in the electric furnace to carbide, the starting material of acetylene, and of cyanamid and the modern fertilizer industry. Platinum can just be melted, and quartz softened, in the hottest flames of combustion; the oxy-acetylene flame, and the oxy-hydrogen flame. But in the electric arc, platinum and quartz and every existing substance, even tungsten and carbon, can be melted and distilled or sublimed. Thus mighty industries have grown up, and many new materials made available to man, as aluminium, silicon, calcium, chromium, the carbides, cyanamid, acetylene, etc.; others produced in a cheaper manner, as alkalies, hypochlorites, phosphorus, magnesium, sodium, etc.

Electricity as such is the most useless form of energy: it is not found in Nature in industrially available quantities, and finds no industrial use as electrical energy; but it is always produced from some other form of energy and converted into some other form of energy—light, mechanical energy, chemical energy, heat, etc. That is,

*Presented at a meeting of the Electrical Section of the Franklin Institute.

electrical energy is entirely the connecting link, the intermediary, by which energy is brought from the place where it is found to the place where it is used, or changed from the form in which it is found to the form in which it is used. Thus, on first sight, it appears a roundabout way, when, for instance, in modern electrical ship-propulsion an electric generator is placed on the steam turbine, a motor on the ship propeller, a few feet away, though it is not different from practically every other use of electric energy: a transmission-link, superior to any other transmission by the flexibility given by the simplicity and economy of conversion.

The most serious disadvantage of electrical energy is that it cannot be stored. It is true, there exists the electric storage-battery, and it is used to a large extent as a stand-by battery in high-grade electric distribution systems to give absolute reliability of service, or as a battery floating on a railway circuit to equalize fluctuations of power, or in special applications, as electric automobiles. It does not really store electrical energy, but stores energy by conversion of the electrical into chemical energy, and reconversion, in discharge, of the chemical into electrical energy.

The economic efficiency of the storage battery—using the term in the broad sense, including interest on the plant investment and depreciation—is so low that the storage battery does not come into consideration in the industrial storage of energy—that is, in making the rate of electrical energy consumption independent of that of energy production. We can best realize this by comparing electrical energy with the chemical energy of fuel: the latter can be stored with perfect economy. Thus, when using fuel as the source of energy—in a steam plant—no serious difficulty is met by the industry, even if the fuel supply is interrupted for months, as in the case of a supply by water, through the closing of the navigation by ice: we would simply bring in a sufficient coal supply to last until the navigation opens again in spring. But with electrical energy from a water-power, we could never dream of storing energy by storage battery to last over the two or three months during which the river runs dry and the water-power fails.

This means that electrical energy must be consumed at the rate at which it is produced, and the cost of electrical energy thereby becomes dependent on the rate of the energy used. This is not the case with most other forms of energy, as, for instance, the chemical energy of fuel. The price of a ton of coal, as determined by the cost of supplying it, is the same whether I dump the coal into a furnace all at once, or whether I use it up at a uniform rate in a small stove, lasting for weeks. If I consume 2,400 cubic feet of gas per day, its cost, and thereby its price, is the same whether I use the gas at a uniform rate throughout the day of 100 cubic feet per hour, or whether I use the entire 2,400 cubic feet in one hour, nothing in the remaining 23 hours: the gas is produced at whatever rate is most economical, stored in the gas-holders, and supplied from there at whatever rate it is required for consumption. If, however, I use 240 kilowatt-hours of electrical energy per day, it makes a very great difference in the cost of supplying this energy, whether I use it at a uniform rate of 10 kilowatt-hours per hour, or whether I use the entire 240 kilowatt-hours in one hour, nothing in the remaining 23 hours. In the former case, 10 kilowatts of generating machinery are necessary in the steam or hydraulic station producing the electrical energy, 10 kilowatts capacity in transmission lines, transformers, sub-station and distribution lines, to supply the demand. In the latter case, 240 kilowatts of generating machinery, 240 kilowatts of line and transformer capacity are absorbed, and that part of the cost of supplying the electric energy which consists of interest on investment in the plant, of depreciation, etc.—in short the fixed cost—is 24 times as high in the latter as in the former case. If the fixed cost approximates half the total cost in a steam plant, or is by far the largest part of the total cost in a hydraulic plant, it follows that, in the case of concentrated energy used during a short time, the cost of electric energy—and with it the price—will be very much larger—many times, possibly—than in the case of a uniform energy consumption.

Thus, owing to the absence of storage, the cost of electrical energy essentially depends on the uniformity of the rate of its use—that is, on the load factor, or the ratio of the average consumption to the maximum consumption.

If I use 240 kilowatt-hours of electrical energy in one hour, nothing during the remaining 23 hours, that part of the cost which is the fixed cost of plant investment and depreciation is 24 times as great as if I used the same amount of energy at a uniform rate throughout the day. In the former case, if somebody else uses 240 kilowatt-hours, but during another hour of the day, the same plant supplies his energy, and the fixed cost thus is cut practically in two—that is, the cost of energy to both of us is materially reduced. Thus, again, the cost of electrical energy, and with it its price, depends on the overlap or not overlap of the use of the energy by different users, the so-called "diversity factor." The greater the diversity factor—that is, the less the different uses overlap and the more their combination, therefore, increases the uniformity of the total energy demand, the "station load factor"—the lower is the energy cost. The cost of electrical energy for lighting, where all the demand comes during the same part of the day, is inherently much higher than the cost for uniform 24-hour service in chemical works, and with the increasing variety of load, with the combination of energy supply for all industrial and domestic purposes, the cost of energy decreases.

Thus, unlike other forms of energy, owing to the absence of energy storage, electrical energy can have no definite cost of production, but, even supplied from the same generating-station, its cost varies over a wide range, depending on the load-factor of the individual use and the diversity-factor of the different uses.

This feature, of necessity, must dominate the economical use of electrical energy in industrial, domestic and transportation service.

The necessities of civilized life consist of two groups: materials and energy. Our transportation system takes care of materials, but cannot deal with the supply of energy, and the failure of an efficient energy supply has been and still is the most serious handicap which retards the advance of civilization. The transportation system could deal with the energy supply only in an indirect manner, by the supply of materials as carriers of energy, and when our railroads carry coal, it is not the material which we need, but the energy which it carries. But this energy is available only to a very limited extent, as heat, and as mechanical power in big steam units; most of the energy demands of civilized life could not be satisfied by it. In any country village far away from the centers of civilization, we have no difficulty to have delivered to us any material produced anywhere in the world; but even in the centers of civilization we could not get the energy to run a sewing-machine or drive a fan without electric power. Thus, just as our steam railways and express companies take care of the transportation and distribution of materials, so civilization requires a system of transmission and distribution of energy, and our electric circuits are beginning to do this; and just as fifty to seventy-five years ago in the steam railroads, steamship lines, etc., the system of transportation and distribution of materials was developed, so we see all around us in the electric transmission systems the development of the system of the world's energy transmission in progress of development. When we see local electric distribution systems combining, the big electric systems of our capital cities reaching out over the country, transmission lines interconnecting to networks covering many thousands of square miles, this is not merely the result of the higher economy of co-operation, of mass production; but it is the same process which took place in the steam railroad world some time ago, as a necessary requirement of co-ordination to carry out their function as carriers and distributors of materials in the case of the railroads, of energy in the case of the electric systems.

We must realize this progress, and the forces which lead to it, so as to understand what is going on, and to assist in the proper development; in avoiding, in the creation of the country's electrical network, whatever mistakes have been made in the development of the country's railway network.

Electricity, thus, is taking over the energy supply required by civilization as the only form of energy which, by its simplicity and economy of conversion, combined with economical transmission, is capable of supplying all the energy demands, from the smallest domestic need to the biggest powers. As we now begin to realize, the economic function of the steam-engine is not the energy supply at the place of consumption, from the chemical energy of coal—it is too complicated and inefficient for this—but it is the conversion of chemical energy of coal into electrical energy in bulk, for transmission and distribution to the places of consumption.

If, then, electric power takes the place of steam power in our industries, etc., it is not merely the substitution of the electric motor for the steam-engine or turbine. Such would rarely realize the best economy. The method of operation in all our industries, and especially those requiring considerable power, is largely—more than usually realized—determined by the characteristics of the power supply, and what is the most economical method with the steam-engine as source of power may be very uneconomical with electrical power supply, and electric power supply often permits a far more economical method of operation, which was impossible with steam-power. Thus the introduction of electricity as the medium of distributing the world's energy demand means a reorganization of our industrial methods, to adapt the same to the new form of power.

For instance, the steam-engine required skilled attendance, and with its boiler plant, auxiliaries, etc., is a complex apparatus, is economical only in large units. Thus, when operating a factory or mill by steam-power, one large engine is used, driving by shafts and countershafts, by pulleys and belts, and possibly wasting half or more of its energy in the mechanical transmission to the driven machines. But we could not economically place a steam-engine at every one of the hundreds of machines in the factory. Substituting electrical power by replacing the engine by one large electric motor would be very uneconomical, as we can place a motor at every driven machine, and these small motors are practically as efficient—within very few per cent—as one big motor would be, and all the belting and shafting, with its waste of energy, inconvenience, and danger, vanishes. With the steam-engine as source of power, to run one or two machines, only, to complete some work, requires keeping the big engine in operation, and therefore is extremely wasteful. With individual electric motors, the economy is practically the same, whether only one or two motors are used, or the entire factory is in operation. On the other hand, with the steam-engine, it makes no difference in the cost of power whether it is in operation from 8 A. M. to 6 P. M., or from 6 A. M. to 4 P. M. With electric power, in the former case the power demand would overlap with whatever lighting load the same supply circuit carries, but would not in the latter case, and the latter case thus would give a better load factor of the electric circuit, and thereby a lower cost of power. Again, with electric power, if very large power demands could be restricted to the periods of light load on the electric-supply systems, this would reduce the cost of power. Nothing like this exists with the steam-engine. Electrical energy thus makes the power-users economically more dependent upon each other, and thereby exerts a strong force toward industrial co-ordination—that is, co-operation.

Another illustration of the industrial reorganization required to derive the full benefit of electric power is afforded by the traction problem. Very often a study of the electrification of a railway shows no economical advantage in the replacement of the steam locomotive by the electric locomotive, even when considering only passenger service. At the same time, an electric railway may parallel the same steam railway, offer better service at lower price, and show financially better returns than the steam railway. But so, also, in the early days of steam, the steam-engine in place of the horse in front of the stage-coach was no success, and still the stage-coach has gone and the steam locomotive has conquered; but it did not by replacing the horse, but by developing a system suited to the characteristics of the steam-engine. The same repeats now in the relation of steam traction and electric traction. The steam-engine is most economical in the largest units, and the economy of steam-railway operation depends on the concentration of the load in as few and as large units as possible; therefore, the largest locomotive which can pass through bridges and around curves. Exactly the reverse is the condition of economy of electric traction: the economy depends on the distribution of the load as uniformly as possible in space and in time—that is, small units at frequent intervals—and, therefore, while steam traction has gone to larger and larger units, in electric traction even the trailer-car, so frequently used in the early days, has practically vanished. Obviously, then, the electric motor cannot economically compete with the steam-engine under the conditions of maximum economy of steam and minimum economy of electric operation, and electric traction under steam traction conditions shows marked economy only in the case of such heavy service that the maximum permissible train units follow each other at the shortest possible interval—that is, give maximum uniformity of load—and thus the economic requirements of both forms of power coincide. These two instances may illustrate the changes in industrial operation which the introduction of electric power requires, and which are taking place to-day.

To conclude, then: Electric energy is the only form which is economically suited for general energy transmission and distribution. Civilization depends on the supply of materials and energy as its two necessities. The supply of materials is taken care of by the transportation systems of the world. The supply of energy is being developed by the electrical transmission system, which, with regard to energy, becomes what the railway system is with regard to materials. Introduction of electric power in place of other forms of power rarely can be a mere substitution, but usually requires a change of the methods of power application, a reorganization of the industry, to secure maximum economy.

Temperature and the Cricket's Call.—It is well known that the cricket's cry occurs at very regular intervals, but recently it was observed that the frequency or number of times per minute depends upon the temperature, at least so a Paris observer affirms, and this will be easy to verify. For instance, at a temperature of 15 deg. Cent. the number is 80 a minute, and at 24 degrees it rises to 120. For each degree there is noticed an increase of four. Should this be true, we thus have a "cricket thermometer" which it only remains to combine with the "bottled frog" barometer in order to have an efficient meteorological outfit.

Fig. 1.—Making the cups, four at one stroke of the press, at the rate of 24,000 per hour.

Fig. 2.—A battery of automatic trimming machines at work on 0.30-caliber cartridge cases.

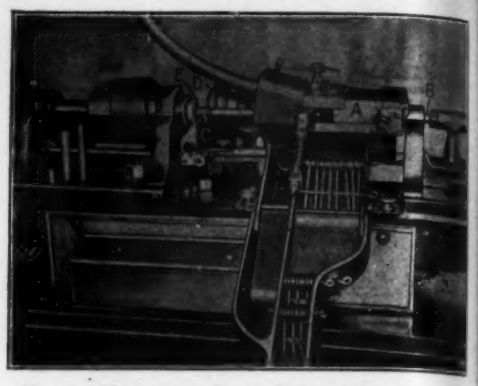


Fig. 3.—Close view of one of the automatic trimming machines shown in Fig. 2.

Drawing Cartridge Cases*

Machines, Dies, Tools and Methods Used by the Frankford Arsenal

By Douglas T. Hamilton

THE difficulties met with in producing cartridge cases from sheet brass are the same as those encountered in practically all drawn sheet metal work. Admitting this, and considering the advances made in cartridge making, it would seem that a description of the methods and tools used for this work should be of general value when modified to suit the various requirements. In this article the data given refer more particularly to the drawing of cases for 0.30 caliber cartridges, the tools and methods used being taken up in detail. The practice followed by the Frankford Arsenal, Philadelphia, Pa., is interesting and presents some novel ideas in this class of work. The writer is indebted to Colonel George Montgomery for the material contained in this article.

*Reproduced from *Machinery*.

Fig. 4.—Chuck for holding blanking, cupping and drawing die blank when machining the hole.

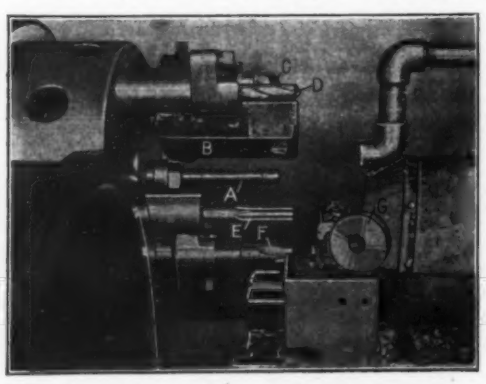


Fig. 5.—Making redrawing die blanks in a Cleveland automatic screw machine.

Fig. 6.—Lapping a redrawing die.

MAKING THE CUPS FROM WHICH CARTRIDGE CASES ARE DRAWN.

The first operation in the making of a cartridge case is to produce a cup, then by successive redrawing operations this cup is reduced in diameter and extended to the required length. Fig. 10 shows the various steps in the sequence of redrawing operations following that of making the cup. From this illustration it can be seen that five operations are necessary to bring the case to the required length—these are called redrawing operations because the work accomplished consists in reducing and redrawing a piece that has already been drawn to cup form. The press used for making the cups from which cartridge cases are made is shown in Fig. 1. It is of the double-action type, and carries four punches and dies, thus making four cups at each stroke. This punch press operates at 100 revolutions per minute, producing 400 cups a minute, or 24,000 cups per hour. The type of blanking and cupping dies used in this machine are shown diagrammatically in Fig. 15, and also in Fig. 11, together with the tools required to make them. Fig. 15 shows the shape of the die more clearly, and gives a comprehensive idea of the action that takes place in the formation of the cup. At *A* the blanking punch is shown in contact with the top face of the brass sheet. At *B* the blanking punch has cut out a disk of the required size and carried it down to the first shoulder in the combination blanking, cupping and drawing die. At *C* the combination cupping and drawing punch has come into operation and has started to form the blank to cup shape; whereas at *D* the blank has been forced completely through the die and has been given the first drawing operation.

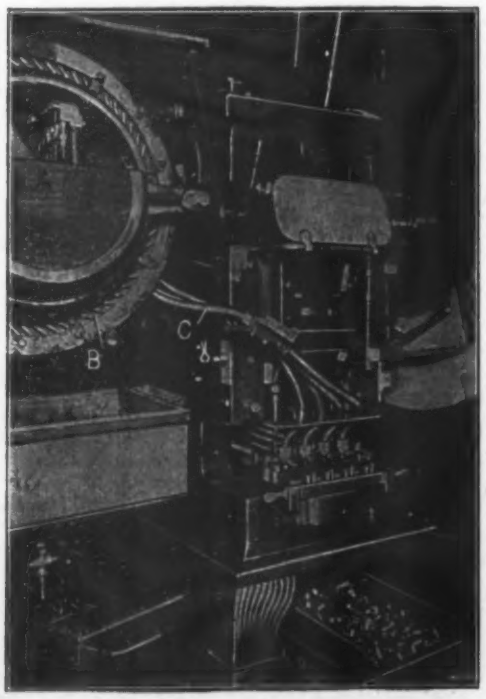


Fig. 7.—Drawing press used for second and third redrawing operations—24,000 cups per hour.

Fig. 8.—A closer view of the machine shown in Fig. 1.

Fig. 9.—Duplex drawing press performing fourth redrawing operation—10,800 cups per hour.

The sheet stock is held on the roll *A* located to the right of the machine shown in Fig. 1, and is drawn into the press under the blanking and drawing punches by means of feed rolls. After the stock passes through the rolls *B*, it is oiled by means of a rag saturated with lard oil that is contained in the tank *C*. The sheet is fed a distance equal to the diameter of the blank plus the width of the web for each stroke of the press (see Fig. 16), and after it has been started by the operator, who uses the handwheel feed illustrated, it is carried on automatically by the feed rolls located at both ends of the throat of the press. As the sheet from which the blanks have been sheared protrudes from the left-hand end of the machine, it passes through a shearing die, which in conjunction with a knife operated by a crank and connecting lever held on the extreme end of the crankshaft, cuts off the scrap, enabling it to be packed in boxes. The chief reason for cutting up the stock in this manner is to avoid having it pile up around the machine and also to enable it to be more easily removed.

The manner in which the dies and punches are laid out in order to economize in stock is shown in Fig. 16. By referring to the upper diagram in this illustration it will be seen that the centers of the four dies are located in a "diamond" shape, thus reducing the width of the sheet required and securing the most satisfactory layout for the punches and dies. The condition of the sheet after the press has made four strokes is shown in the lower portion of the illustration, which indicates the progression followed in cutting out the blanks.

SETTING DRAWING PUNCHES AND DIES.

To set drawing punches and dies properly requires considerable experience, as this is a difficult task under the most favorable conditions. The dies and punches are usually aligned with each other by setting them in the approximately correct position, then running through a few cups and noting the results. In the type of die-holder shown in Fig. 8, it is not necessary, of course, to reset the dies when they have been removed for grinding, if proper attention has been paid when they were first set up. This is not the case, however, with redrawing dies, as will be explained later. One peculiar point in making cups that causes considerable trouble is that it is practically impossible to produce a cup with a straight top; that is, one in which the metal is drawn to the same extent on one side as it is on the other.

The reason for a cup drawing irregularly in this manner is not due in all cases to inaccurate setting of the punches and dies, but generally to a variation in the thickness of the sheet from which the blank is cut out. It is a peculiar fact, but nevertheless true, that it is practically impossible to roll sheet metal uniform in thickness; that is to say, the sheet is thicker in the center than it is at the outer edges. The reason given for this is that the rolls, even though they be 8 or 10 inches in diameter, spring to a slight extent in the center—where they are unsupported except by their inherent strength—and thus produce a sheet of varying thickness throughout its width. Another difficulty experienced in making cups is the striking of hard spots in the metal. It is obvious, of course, that if the stock is not of a uniform hardness, the softest spot or portion will draw much more than the harder portion, and hence, a cup having one side longer than the other will be obtained. Not only will the top edge be irregular, but the walls will also be of uneven thickness. It is claimed by those who have had experience in this work that it is impossible to rectify any defect of this kind in the succeeding redrawing operations. When a cup is once started with a wall of unequal thickness, this condition prevails until the final drawing operation, so that it will easily be seen that great care must be exercised in making the walls of the cup of uniform thickness if a satisfactory product is to be obtained.

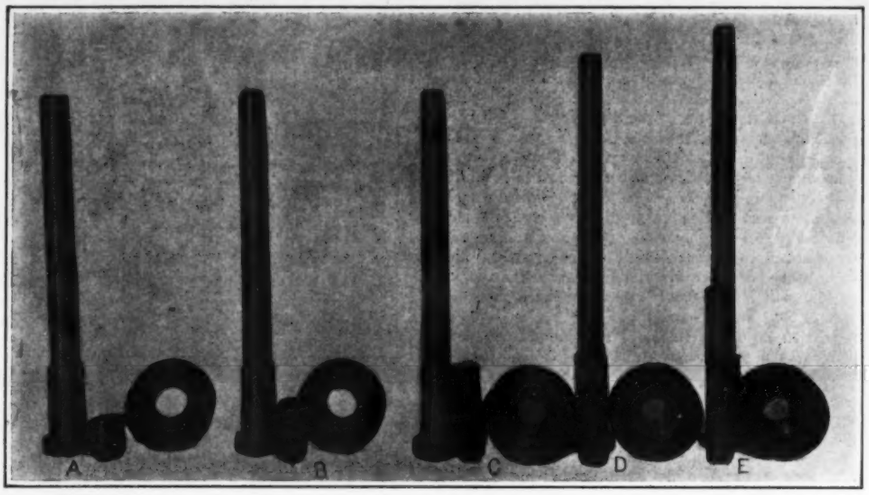


Fig. 10.—Sequence of redrawing operations on a 0.30 caliber cartridge case, and tools used.

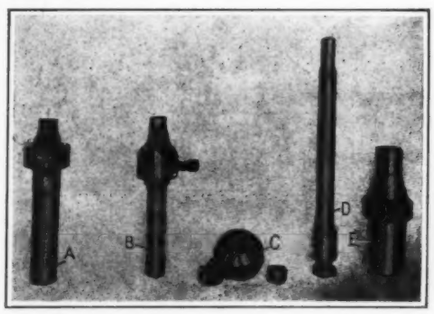


Fig. 11.—Combination blanking, cupping and drawing punch and die, and the tools used for making the die.

ANNEALING AND REDRAWING OPERATIONS.

After the cups are made in the manner described above it is the general practice to anneal, wash and dry them. Then they are ready for the first redrawing, or second drawing operation. The temperature to which the cup is heated for annealing varies from 1,200 to 1,220 deg. Fahr. The manner of handling the cups after they have been annealed, washed and dried, is to carry them in trucks, which are lifted from the floor of the annealing room to a track located above the drawing presses. These trucks are provided with false bottoms and are run along the track until they are directly over the hopper which feeds the cups to the punch press. The false bottom is then removed, allowing the cups to drop from the chute into the hopper *A* of the drawing press, Fig. 7, from which they are removed by a feeding device consisting of a wheel in which pins *B* are set at an angle of about 45 degrees with its horizontal axis. These pins are pointed, enabling the shell to be located on them, mouth first. The pins are rotated inside the hopper so that they catch the cups and deposit them in close-wound spring tubes *C*.

These tubes pass from the hopper down to the feeding slides of the drawing press (see Fig. 7) and as the shells drop out of the tubes they are caught by fingers held on the slides and carried over into line with the dies and punches. When the slides have advanced to their extreme forward positions, the punches descend and force the cups through the drawing dies, depositing them in a box located under the press. The slides are operated from the crankshaft through bevel gears and a connecting-rod that transmits power down to a horizontal shaft carrying a series of four cams. These cams contact with rollers held in the feeding slides and thus transmit the desired movement to them. The rolls are held in contact with the cams by coil springs. The machine shown in Fig. 7 operates at 100 revolutions per minute, and as four cups are drawn per stroke, it is evident that this machine has a productive capacity of 24,000 cups per hour. The drawing press shown in this illustration is used for performing the second and third redrawing operations, shown with the die and punch used at *B* and *C* in Fig. 10.

FIRST, FOURTH AND FIFTH REDRAWING OPERATIONS.

The first, fourth and fifth redrawing operations are handled in machines of a type similar to that shown in Fig. 9, which are provided with only two punches and dies instead of four, as was the case with the machine shown in Fig. 7. The feeding of the shells to the slide that carries them to the dies is practically identical with that shown in Fig. 7, but the slide is operated in a different manner. In this particular machine the slides *A* which serve as a means for carrying the cups from the feeding tubes *B* over into line with the drawing dies are actuated in their movement by means of a bellcrank

Fig. 12.—Making combination blanking, cupping and drawing dies.

Fig. 13.—"Spouting" a redrawing die—hardening the hole and leaving the exterior soft.

Fig. 14.—Hardening a redrawing punch—note method of dipping.

lever receiving power from a cam held on the crankshaft *C* of the press.

While the shells are fed to the punch with the mouth up, it sometimes happens that one will pass down the feeding tubes to the slide the wrong way, that is with the bottom up. Now should such a shell be allowed to pass over into line with the die, it would mean that the punch would be broken and the die either broken or damaged to such an extent that it would be unfitted for use. It is not uncommon also to have shells pass down to the slide that are dented or otherwise defective, which would prevent them from feeding into the die properly. Should such a shell pass down the feeding tubes and stick in one of the slides, it would mean that the punch would come down on the slide and break, not only putting the machine out of commission for a time, but perhaps causing serious damage to the attendant as well.

In order to provide against such accidents, Mr. August A. Plate, general foreman, invented an ingenious tripping device that is applied to this machine and works very satisfactorily. This device, while comparatively simple in construction, is positive in its action, and has been the means of saving a lot of money in the cost of dies and tools. It also enables one attendant to run four instead of two machines. Essentially, this device consists of a projecting stud held in the crankshaft of the press, and which when the feeding slide is operating normally, passes through a slot cut in a lever that is connected with the bellcrank lever operating the slide.

Now, if for any reason the slide should be prevented from making a complete forward or backward stroke, this projecting pin would not pass through the slot in the lever mentioned, but would force the lever out, knocking out the lever *D*, which transmits a movement through the links *E* and *F* and bellcrank *G* down to the tripping lever *H*. This knocks the clutch operating lever *I* off the catch—throwing in the clutch and stopping the operation of the press. It can therefore be seen that this tripping device is of simple construction, but is effective, owing to the fact that when the slide does not complete its movement the clutch is thrown in before the ram of the press reaches the top of the stroke, so that the machine is stopped before it has a chance to complete another stroke.

FINAL REDRAWING OPERATION.

The fifth redrawing is accomplished in a press similarly equipped to that shown in Fig. 9. These presses operate at 100 revolutions per minute, and turn out 12,000 cups per hour. Several annealing operations take place between the time when the cup leaves the first redrawing operation and the time when it is ready for trimming. These will not be described in the present article. Before the fourth redrawing operation is accomplished the shells are taken to a heading machine of the horizontal type where they are "bumped." This operation is accomplished in order that in the successive redrawing operations the head of the shell will not be reduced too much in thickness.

The 0.30 caliber cartridge case has what is known as a solid head; that is, the top portion of the shell that contains the primer is not indented to form a pocket for the primer, the pocket itself being simply a hole forced into the head. This type of cartridge has been found necessary for use with smokeless powders. The former method used in making 0.30 caliber cartridge cases was to form the pocket by forcing in the head which was very little thicker than the sides of the shell near the head. This construction, however, was found to be too weak for smokeless powders, as the head would blow off. The "bumping" is a very simple operation and is somewhat similar to heading, except that the punch is perfectly flat and simply gives the shell a blow, upsetting it slightly and flattening it so that in the two final redrawing operations—fourth and fifth—the metal at the head is not stretched to any appreciable extent.

TRIMMING A CARTRIDGE CASE TO THE EXACT LENGTH.

As was previously mentioned, it is practically impossible to draw a shell that will not have an irregular top edge and also that will not become distorted or cracked to some extent. This makes it necessary to draw the case much longer than actually required, and to trim off the surplus material. The removal of this excess amount of stock is accomplished in machines that are operated automatically. A battery of these trimming machines at work on 0.30 caliber cartridge cases is shown in Fig. 2, while Fig. 3 shows a closer view of one of the machines and gives a clear idea of its working mechanism. As will be seen upon reference to Fig. 2, these trimming machines are arranged in such a manner that the various hoppers can be filled from an overhead conveying system. This arrangement consists of a track similar to that used in the drawing press department previously referred to, and enables one man to attend to an entire line of presses. The track accommodates a truck in which the shells are carted along the line and from which they are ejected through a false bottom, dropping into the hoppers located over the machines. The feeding of the shells down to the trimmer is accomplished by the same type of hopper as previously described, but the subsequent handling is somewhat different. As the shell descends from the hopper it passes through a locating cage *A* from which it is carried forward by a plunger *B* and is located on the cutting-off punch *C*. Here it is held by friction while a circular trimming tool *D* advances and trims off the surplus stock. The shell and trimming are then ejected from the cutting-off punch by a sleeve *E* operated from the left-hand end of the machine, the shell being deposited in one box and the trimming in another; two separate channels are provided as shown clearly in Fig. 3.

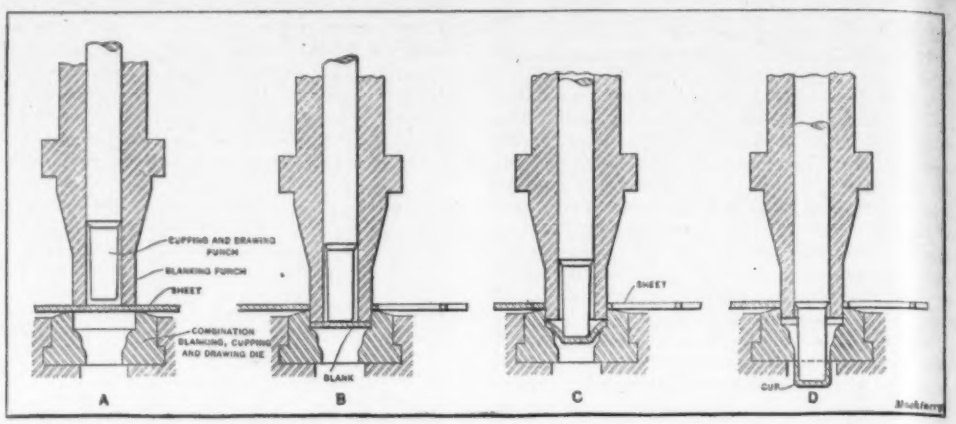


Fig. 15.—Progressive steps in the blanking, cupping and first drawing operations on the cartridge case.

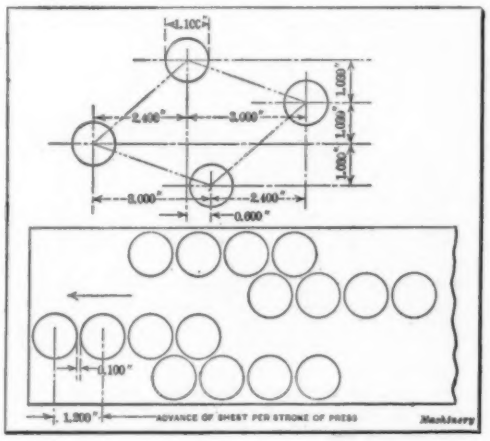


Fig. 16.—Manner of laying out combination blanking, cupping and drawing dies in order to economize in stock.

MAKING COMBINATION BLANKING, CUPPING AND DRAWING DIES.

While the making of combination blanking, cupping and drawing dies does not differ materially from ordinary tool making, there are a few points in connection with this work that it might be well to explain. The die blank is made from a special grade of Firth-Sterling steel containing from 1.11 to 1.30 per cent carbon. This is an extremely high carbon steel, but has been found satisfactory for this class of die owing to the great wear that it is subjected to when in use. The first step, of course, in making one of these dies is to cut off the blank from a bar of stock, and then by means of drills, reamers, etc., to shape the hole in the die to the correct form. Fig. 11 shows one of these dies at *C* together with a blank and a cup made from it, while *D* is the combination cupping and drawing punch and *E* the blanking punch.

Fig. 12 shows a toolmaker completing one of these dies, and Fig. 4 shows a close view of the chuck used for holding it. The manner in which the die is held while being drilled, counterbored and reamed is identical with that used when it is set up in the press, so that in this way the conditions in both cases are as nearly alike as possible. The chuck consists of a female center *A* in which a recess is provided that fits the external body of die *B*. The outer end of this center is turned and threaded to fit a cap *C* that is machined to correspond with the other end or smallest diameter of the die *B*. This cap holds the die rigidly in position while it is centered with the female member *A*. In addition to a drill, and, of course, a boring tool to true up the hole, two tools are used for finishing the hole in this die. The first or roughing tool *B*, Fig. 11, is of the flat type, having one cutting edge, while the finishing tool *A* is of somewhat similar shape, but has considerably more circumference so that a rounder hole will be produced. The first tool is used merely for roughing-out purposes and for bringing the hole to its approximate shape.

MAKING REDRAWING DIE BLANKS.

The blanks for redrawing dies are turned out in Cleveland automatic screw machines, and are ready for the final reaming operation when they drop from the machine. This method is commendable in that it reduces the cost of the dies to a minimum. The steel used for making these dies is a special grade of Firth-Sterling steel containing from 1.11 to 1.30 per cent carbon, and for the particular die *G* illustrated in Fig. 5, a bar 1¾ inch in diameter is used. This die is a second redrawing operation die for a 0.30 caliber cartridge case, and is 1 23/32 inch in diameter by ½ inch thick. In order to have the hole true with the external diameter, great care is taken in spotting the work and then removing the hole entirely from the next blank, using a fairly wide cut-off tool. The order of operations accomplished in the proper sequence is as follows: First, feed stock to stop *A;* second, turn external diameter with box-tool *B* held in turret and spot with a drill *C* retained in the same holder; third, drill with drill *D;* fourth, ream straight portion of hole with reamer *E;* fifth, bell-mouth with reamer *F*, and face with a tool held on the rear cross-slide; sixth, cut-off with a tool held on the front cross-slide.

The drawing dies, after being rough-formed in the manner illustrated, are then taken to the tool-room, where they are reamed out to the exact diameter and bell-mouthed to the correct shape, after which they are ready for hardening. For hardening, the dies are heated in a muffle furnace to a temperature varying from 1,400 to 1,450 deg. Fahr., and are then "spouted" as illustrated in Fig. 13. The spouting of the die consists in directing a stream of water through the hole in order to harden it and at the same time leave the external diameter practically soft. The reason for this is that the die, after hardening, is not drawn, and if the entire blank were hardened it would break very easily. Having the external diameter soft increases the strength to a considerable extent, and the dies wear much longer and do not break as easily.

When spouting, the die is held in a cage formed in the base of the bracket *A* and then the funnel *B* (which is similar in shape to an ordinary oil funnel except that the lower tapered tube is left off) is placed over it, the water being directed through this funnel and thence to the hole in the die. The funnel is provided with a handle to enable the operator to place it quickly in position over the die after the latter has reached the proper temperature, and has been placed in the fixture. The operator removes the die with a pair of tongs, holding the tongs in one hand and the funnel in the other.

Great care must be taken in heating this grade of steel because of its high carbon content. A variation of 10 deg. Fahr. one way or the other from the temperature found most satisfactory will in many cases make the die defective for the operation that it is to accomplish. It has also been found necessary to heat the dies for various operations to different temperatures; that is to say, the die that would be used for a first redrawing operation would be heated to a different temperature from one that would be used for the fifth redrawing or final drawing operation. The reason for this is that the pressure exerted on the die, by forcing the cup through it with the punch, on the first drawing operation, is much greater than that for the final drawing operation, and hence the die cannot be as hard and must have a more porous grain to withstand the additional pressure.

LAPPING REDRAWING DIES.

After hardening, redrawing dies are lapped in the manner illustrated in Fig. 6. The die is held in a holder resembling somewhat in shape that used in the drawing press, which is held in the chuck of the speed lathe. For lapping, a lead lap is used. This is held on a steel plug provided with a handle driven through it at right angles to the lapping portion, so that the operator can grip it with both hands and thus hold the plug in the proper position in relation to the hole in the die. The speed lathe in which the die is held is operated at from

2,000 to 2,400 revolutions per minute, and the spindle is always kept a snug fit—also there must be no end play. A mixture of lard oil and No. 10 emery is used for lapping, this being found best for both the roughing and finishing operations. The mouth or bell-mouthed portion of the die is lapped with emery cloth of the same grade—No. 10. The lapping of a drawing die is an operation that must be very carefully handled. Not only must the hole be of the correct size, but the radii of the bell-mouthed portion must be exact. The correct lapping of the die is more a matter of experience than anything else, and it is practically impossible to give any definite information on the subject. One point, however, that should never be ignored is the fact that the lap should always be presented in a line parallel to the axis of the die. If it is tilted over the least bit to one side or the other a hole will be produced that will not only be out of round, but that will not be straight; that is, if the die were placed on the arbor, it would be found to run untrue because the hole would not be exactly in the center of the blank on both sides.

After the dies are lapped to the correct size and shape, they are ready for use in the press and are then turned over to the drawing press department. Drawing dies for all redrawing operations up to the final operation are used until they have worn approximately 0.0017 inch large. When they have become worn to a size this much greater than the actual diameter of the cup required, they are taken out of the press and annealed. The dies are then reamed out to the next size larger—that is for the previous redrawing operation than that for which they were originally made—and used over again. This is repeated until the dies have been used five times. Redrawing dies made from Firth-Sterling steel of the carbon content previously given are good for making 40,000 cups before they have become worn too large. The peculiar point about this steel is that it does not warp out of shape in hardening and also does not produce any scratches on the work. It is of extremely fine grain, hardens well and produces a shell free from scratches and other imperfections. The only thing that makes it unfit for use is when it becomes worn too large. Otherwise the condition of the hole in the die is as good at the completion of 40,000 cups as it was when first used.

MAKING REDRAWING PUNCHES.

Redrawing punches are also made from Firth-Sterling steel, but the carbon content for the punch is considerably lower than that used for the die, and never should exceed over 0.60 per cent. There are a few points that require careful consideration in making drawing punches. In the first place, the stock should be centered as true as it is possible to get it. There is a good reason why this operation should be carefully done. If the piece of stock from which the punch is to be made has not been centered true, the finished drawing punch when hardening will be bent out of shape. The reason for this is that when a bar that has been incorrectly centered, so that it runs eccentric, is turned, more stock is removed from one side than the other, and the turning, instead of being parallel with the grain, cuts across it; hence the ability of the steel to resist deflection in hardening is not as great as it would be, had the support not been removed from one side. The explanation given for this is that in rolling bar stock the fiber or grain of the metal is drawn out in practically a straight line and when this condition does not exist in the finished article distortion takes place, because, in cooling, the fibers of the stock revert to their original positions parallel with the axis of the bar.

Another point that is of considerable importance is that never less than 1/32 inch of material should be removed from the bar if the finished piece made from it is to be hardened. There is a certain decarbonizing portion surrounding a bar of stock that prevents the steel from hardening properly, and this decarbonizing portion should always be removed from those parts of the punch that must be hardened; if not, soft spots will be experienced.

The drawing punch should be heated in a muffle furnace very slowly until it has obtained the correct temperature, and while being heated it should be constantly rotated to prevent warping. The temperature to which drawing punches are heated varies from 1,400 to 1,425 deg. Fahr. They are quenched in a bath consisting of 15 parts water and 1 part common potash, and are dipped in a vertical position as illustrated in Fig. 14.

On the Relation of Mathematics to Engineering*

Anticipating the Needs of the Engineer of To-morrow

By Prof. Arthur Ranum

How can we reconcile the fact that many a successful engineer uses very little mathematics in his work, with the further well-known fact that the profession of engineering rests to a large extent on a mathematical foundation? This question has many phases, one of which we can answer by pointing out that there is a vast difference between developing the mathematical theory that applies to an engineering problem and merely making use of the theory after it has been developed and put in tabular form by someone else. The latter process does not require very high mathematical attainments, but is sufficient for many practical purposes. In order to gain more light however, on this and other similar questions, let us try, if possible, to determine precisely what contributions mathematics has made to engineering; by looking back into the past, perhaps we shall discover some general law that will enable us to peer a little into the future.

Engineering has been defined as the art of directing the great sources of power in nature for the use and convenience of man. Now power implies energy, force, motion. Modern science has shown that all the phenomena of nature, including heat, light and electricity, are manifestations of energy, modes of motion. In order to direct the forces of nature, we must know how they act, we must understand the laws underlying the different kinds of motion, molecular as well as molar. Mechanics is then the fundamental science on which engineering depends. The other branches of physics reduce, in the last analysis, to mechanics. Now in the case of a moving body, molecule, or electron, the first thing we want to know is its velocity and the next is its acceleration. Both of these are rates of change or derivatives. Hence it is the most natural thing in the world to introduce the calculus into mechanics. The mathematical notion of a derivative is not something imposed upon mechanics from without; it belongs to the very essence of the science. Every waterfall, every bird on the wing, every ray of sunlight, every flash of lightning, when interpreted in mechanical terms, speaks the language of the calculus.

We must guard, however, against the error of supposing that mathematics can furnish us with any of the facts on which the laws governing physical phenomena are based. These facts can only be found by observation and experiment. But when once a precise physical law has been discovered, the function of mathematics is first to provide it with a language adequate to express all its complex and delicate content, and second, to interpret its hidden meaning and derive the consequences that flow from it, when the other known physical laws are taken into account. This means that the mathematician builds on the given foundation of experimental laws a logical structure, which often contains new theorems of far greater physical significance than the original ones from which they are derived. It is in this sense that mathematics has been described as the master-key that unlocks the secrets of nature.

Sometimes, moreover, a mathematical development of this kind leads in the most unexpected fashion to important practical applications. The delicate and exhaustive experiments and far-reaching generalizations of the physicist, the profound and searching analysis and rigorous thinking of the mathematician, the ingenious and practical resourcefulness of the inventor, are all three necessary factors in the progress of engineering. The influence of the last of these, the inventor, although more direct and easily understood than the others, is not therefore necessarily the most important. On the contrary, his work is often a mere corollary of the scientific research which has prepared the way for him. The history of science furnishes countless illustrations of this. The development of electricity in general, and the discovery of wireless telegraphy in particular, are striking examples, which I cannot describe better than by quoting from Whitehead's recent "Introduction to Mathematics."

"The momentous laws of electric induction were discovered by Michael Faraday in 1831-32. Faraday was asked: 'What is the use of this discovery?' He answered, 'What is the use of a child—it grows to be a man.' Faraday's child has grown to be a man and is now the basis of all the modern applications of electricity. . . . His ideas were extended and put into a directly mathematical form by Clerk Maxwell in 1873. As a result of his mathematical investigations, Maxwell recognized that under certain conditions electric vibrations ought to be propagated. He at once suggested that the vibrations which form light are electrical. This suggestion has since been verified, so that now the whole theory of light is nothing but a branch of the great science of electricity. Also Herz, a German, in 1888, following on Maxwell's ideas, succeeded in producing electric vibrations by direct electrical methods. His experiments are the basis of our wireless telegraphy."

We shall appreciate the important place which mathematics occupies in practical affairs, if we try to imagine what would happen if all the contributions which mathematics has made and which nothing else could make to the progress of engineering were suddenly withdrawn. The result would obviously be terrific; it would mean nothing less that the total collapse of all industry and commerce, and indeed the complete annihilation of all the external evidences of our material civilization.

"But why," asks the practical man, "do mathematicians and physicists concern themselves so much about certain fields of research which can never, in all likelihood, lead to practical results?" Two good reasons can be given. First of all, truth is one and indivisible; every part of the structure of truth has some bearing on every other part. Sometimes the most theoretical investigation is nearest to the most practical application. Nothing could at first have seemed further removed from the concerns of our daily life than the study of the radiant energy connected with Crooke's tubes, on the one hand, or the use of the so-called imaginary numbers, on the other—and yet look at the practical value of X-rays and of alternating currents, the latter depending essentially on these same imaginary numbers.

Moreover, certain branches of mathematics are no less important because their influence is indirect. In order to gain a thorough understanding of alternating currents we must study the properties of Fourier's series; and to understand Fourier's series we must study the theory of functions and of differential equations. These latter again depend on various other disciplines like the theory of equations and the theory of groups. We can never know too much about the space in which we live; hence the practical value of the modern developments of geometry, projective and metrical, analytic and synthetic, algebraic and differential, euclidean and non-euclidean, and even n-dimensional, because from one important point of view our ordinary space is four-dimensional.

But a more fundamental reason why truth should be pursued for its own sake is the simple fact that man is endowed with a divine curiosity, a desire to penetrate the secrets of nature. He wants to understand, among other things, the outer physical universe in which he is immersed and also the inner universe of logical thought revealed by mathematics. Are not the wonders of non-euclidean geometry and non-newtonian mechanics sufficiently valuable in themselves, without any reference to their practical bearing? The recent discovery that the atom, formerly thought to be indivisible, is really a complete world in itself, a sort of solar system so to speak, is surely of immense interest to every thinking person merely as affording a glimpse into one of the hidden recesses of truth.

Although the sciences of mathematics and physics are very closely related, they have not always kept perfect step with one another in their development. This is due partly to insuperable difficulties on the one side or the other and partly to an unfortunate lack of co-operation between mathematicians and physicists. For instance, the physicist has sometimes come to the mathematician for the solution of a problem, but has been compelled to wait a long time for the proper theory to be developed. A classic instance is the problem of three bodies in astronomy, which was discussed in detail in the last issue of the SCIENTIFIC AMERICAN SUPPLEMENT.

More often, however, the mathematician develops a body of doctrine, and only after a long interval does it turn out to have important applications to physics or engineering. The pure mathematics of one epoch becomes the applied mathematics of a later epoch. Maxwell's theory of electricity, before referred to, is a case in point; the mathematics he used depends essentially on principles which had been known for a long time. The discovery of the calculus was due to the attempt to find the lengths and areas of curves; later its immense significance in the science of mechanics was realized. The conic sections were investigated by the Greeks over two thousand years ago; and even to-day we are constantly finding fresh uses for them. Logarithms were discovered three hundred years ago, and the logarithmic function (or the compound interest law) now proves to be one of the commonest and most important laws governing the phenomena of nature. The

* Reproduced from the *Sibley Journal of Engineering*.

elliptic functions were first invented as pure mathematics, and then applied to the motion of the pendulum and other physical problems. The theory of groups has found a most unexpected application to the problem of determining the different types of crystal structure. Very recently the principle of relativity has appeared on the scene and threatens to revolutionize the science of mechanics; but its natural geometric interpretation turns out to be a non-euclidean geometry that has been known for thirty years or more.

The history of Fourier's series is a fine illustration of the mutual dependence of mathematics and physics. Originally due to the solution of a problem in the flow of heat, it soon acquired a position of capital importance in pure mathematics as the general expression for a simply periodic function. But since periodicity is a well-nigh universal law of nature, Fourier's series soon returned to the physical camp, where it now serves as the appropriate vehicle for expressing a large number of different kinds of periodic motion, including sound waves and alternating currents.

Can we make any prediction as to the future prospects of engineering? If progress continues along the lines followed in the past, one thing, at least, we can foresee with great confidence—the pure and applied mathematics of to-day, with its enormous and ever-growing body of splendid achievements, will surely lead, sooner or later, to a variety of practical applications and new inventions that will startle the world. The material and utilitarian progress of to-morrow will depend largely on the scientific progress of to-day. Moreover, the increasing demand for accuracy and efficiency in engineering can be met only by broadening and strengthening its mathematical foundations. Many an engineering student of to-day will live to see the time when those engineers who are leaders in their profession, who are capable of meeting novel conditions where originality of thought and action are required, will be men who are better equipped on the scientific side than we think necessary to-day; they will be men who are thoroughly trained in the use of many of the higher branches of what we now call pure mathematics.

Method for the Graphical Construction of a Direct Reading Scale for Wheatstone Bridge

By J. Carl Fisher

In some of my work I found occasion to graduate a direct reading scale such as is used on the Kohlrausch-Wheatstone bridge, as sold by most manufacturers. A graphical method seemed desirable, and I finally found a simple one which serves the purpose admirably.

Referring to the upper diagram, AB is a straight wire which is divided into two variable segments P and Q by the slider S. This in turn is connected by a wire through the galvanometer G to the midpoint between the unknown and known resistances, x and R respectively. The current from the battery divides at A, part flowing through PQ and part through xR to B. The fall of potential, or pressure, is the same in the two branches, PQ and xR. Hence, if S is at such a position that the fall of potential is the same through P as through x and through Q as R, M and S are at the same potential and there will be no current forced through the galvanometer. We then say a balance has been obtained and the proportion $P:Q = x:R$ holds true. If we call the length $A\ B, l$, then $Q = l - P$; also let the ratio $x:R = m$ a constant. Then we have $m = P/(l - P)$, and $P = ml/(m + 1)$. If we take successive arbitrary values of m, we may find P in terms of l and make out a complete table from which a scale could be graduated by laying off successive values of m with dividers. This much I believe is familiar and I have given it merely to make clear what follows.

Referring now to the large diagram, assume a scale unit which is one tenth of the length to be graduated, lay off an indefinite line EA and graduate it in equal parts, starting from D, distant one unit from E, as zero. At division 9 erect a perpendicular AB which is the length of the scale to be graduated. Through C on this line, and distant one unit from B and D, draw a straight line which thus makes an angle of forty-five degrees with EA. Erect perpendiculars from the division points of DA to this diagonal, and through their points of intersection draw lines from E intersecting AB. The division points thus obtained on AB should be marked with the same numbers as the corresponding points on DA. So much for the construction.

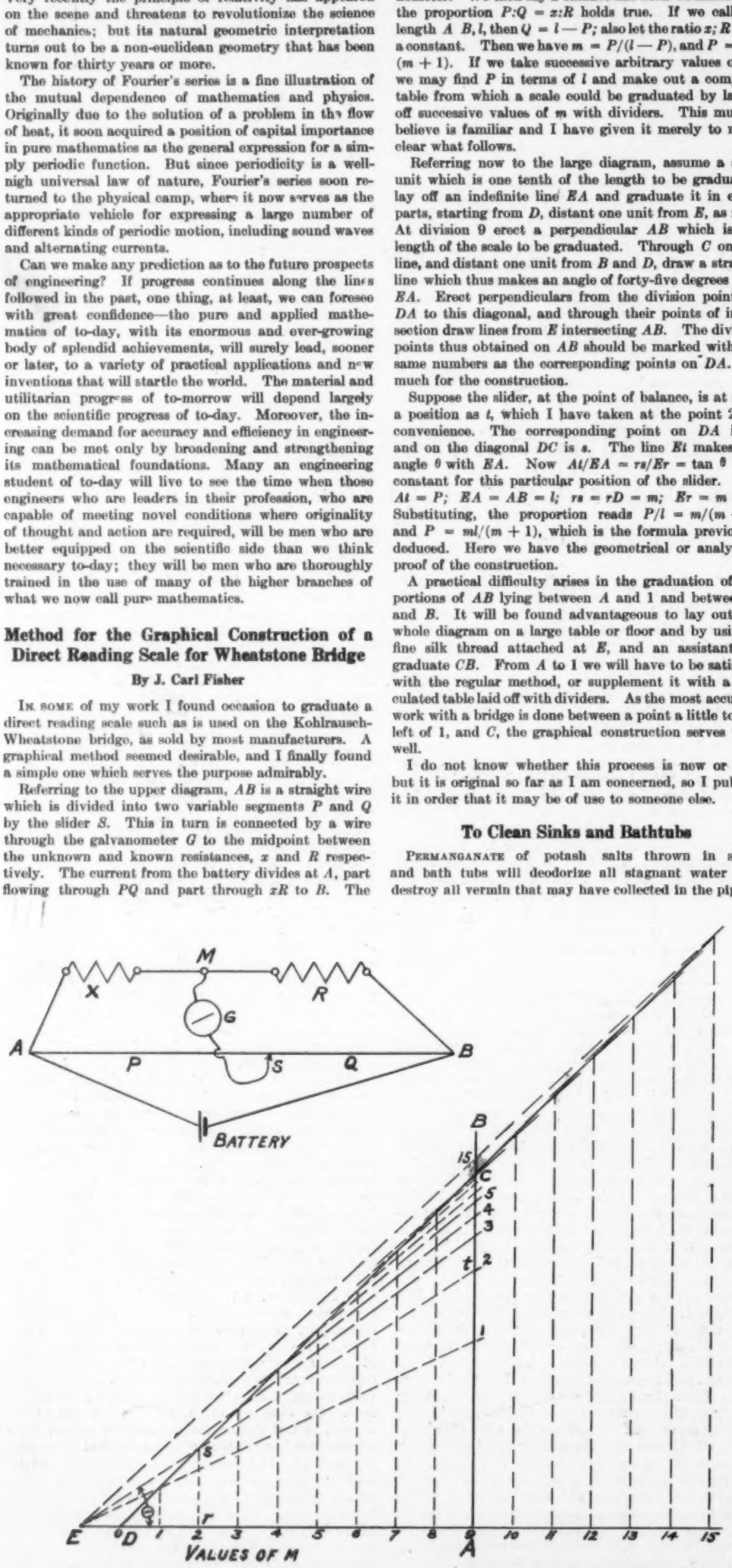
Suppose the slider, at the point of balance, is at such a position as t, which I have taken at the point 2 for convenience. The corresponding point on DA is r, and on the diagonal DC is s. The line Et makes the angle θ with EA. Now $At/EA = rs/Er = \tan\theta = a$ constant for this particular position of the slider. But $At = P$; $EA = AB = l$; $rs = rD = m$; $Er = m + 1$. Substituting, the proportion reads $P/l = m/(m + 1)$ and $P = ml/(m + 1)$, which is the formula previously deduced. Here we have the geometrical or analytical proof of the construction.

A practical difficulty arises in the graduation of the portions of AB lying between A and 1 and between C and B. It will be found advantageous to lay out the whole diagram on a large table or floor and by using a fine silk thread attached at E, and an assistant, to graduate CB. From A to 1 we will have to be satisfied with the regular method, or supplement it with a calculated table laid off with dividers. As the most accurate work with a bridge is done between a point a little to the left of 1, and C, the graphical construction serves very well.

I do not know whether this process is new or not, but it is original so far as I am concerned, so I publish it in order that it may be of use to someone else.

To Clean Sinks and Bathtubs

Permanganate of potash salts thrown in sinks and bath tubs will deodorize all stagnant water and destroy all vermin that may have collected in the piping. It is harmless, and any amount will work until it is all used up. It does not color the porcelain fixtures, but should not be splashed on the walls.



The World's Machines

From information published by the *Annuaire de la Statistique*, it appears that Germany exports the most machines and Russia imports the most. The following figures give the relative money value of machines imported and exported for various countries (1910):

	Exportations.	Importations.
Germany	575	80
England	526	77
United States	372	54
France	63	195
Belgium	62	71
Austria-Hungary	32	113
Italy	6	90
Russia	3	307

It is also to be remarked that the exportation figure for Germany is constantly increasing. In the following year, 1911, it reached 680.

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